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AIR RECEIVER PRACTICE

By Frank Richards.

Among the practical details of compressed-air practice, the function of the air receiver has perhaps received less than its proper share of attention. Recent consideration of its use in these columns has been interesting and profitable and suggests some further discussion.

Usually every compressor is provided with a receiver or air reservoir, and almost invariably it is placed quite near the compressor. I am beginning to ask myself why the air receiver is considered such a necessary adjunct, why, if used, it is located so near the compressor, and some other questions implied by these.

As a reservoir for the storage of the air and for the maintenance of the pressure when the compressor stops, or when temporarily the demand for air exceeds the capacity of the compressor, it is of little account, since usually the total capacity of the receiver does not exceed one minute's output of the compressor with which it is connected. When the air is being used as fast as it is compressed, if a sudden stoppage of the compressor occurs the pressure falls so quickly that it is usually too low for efficient service in half a minute or less. The air in long pipe lines of ample capacity will, of course, extend the time somewhat, but it is always found that when the air is used for constantly working tools, or other apparatus, the storage feature is not much to be counted on.

An experience which came early to the first extensive users of compressed air, the rock-drill runners, was with the trouble and delay caused by the freezing up of the exhaust passages of the drills. This freezing up was ultimately realized to be a result not alone of the fall of temperature of the air as it expanded in doing work, but was due also to the pres-

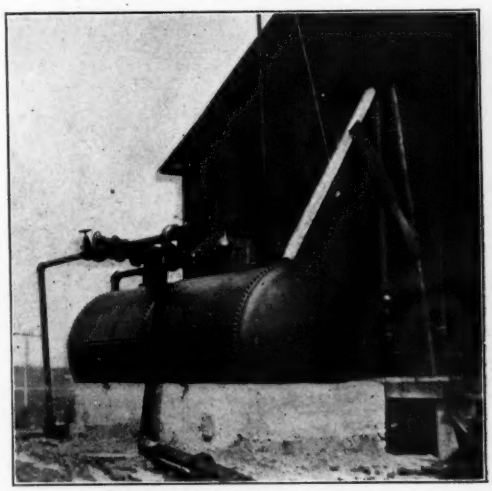


FIG. 1.

ence of released moisture in the air, which moisture could be deposited and frozen in accumulating masses in the exhaust passages. The freezing temperature alone could not make trouble of the kind that was actually encountered. If there is no free moisture to be deposited and frozen, there can be no choking up. This freezing up is generally more cheaply and effectively prevented by the elimination of the moisture than by maintain-

ing the temperature of the air above the freezing point. This is not in any way belittling the value or importance of air reheating. The desirability of having dry compressed air is generally realized, and it is commonly understood that the real and most important service of the air receiver is to give the air an opportunity to drop its superfluous moisture before it is delivered to its work, it being assumed that the air will most accommodatingly do this in the receiver, which is, therefore, provided with a drip cock, from which it is expected that the water is to be drawn. Generally speaking, it may be said that the air which passes through an air receiver as ordinarily installed does not emerge in a very dry state. In Fig. 1 is shown a horizontal air receiver connected to a motor-driven compressor used on one of the New York State barge canal contracts. It may be said incidentally that, from a mechanical-engineering point of view, everything connected with this compressed-air installation is excellent. The piping and all accessories are perfect. Air leakage and such troubles are impossible here, and the cost of maintenance of the plant is a minimum.

The air from the compressor passes into the receiver at the side near one end, and out at the top, near the other end. As the air enters the receiver with the heat of the final compression, and as, after the receiver once gets as hot as the air, there is nothing in the receiver to cool the air and it passes out at about the same temperature as when it enters. From the location of the inlet and outlet pipes we may well assume that when the compressor is running, the entire contents of the receiver are in motion, and it would be rather absurd to assume that the air is appreciably cooler at one point of the receiver than at another. With a temperature above 300 degrees Fahrenheit, there would be no apparent reason why there should be a difference of a single degree, or why, so far as temperature was concerned, the air might not be taken from one part of the receiver as well as from any other.

Nor would it make any difference, so far as the deposition of moisture in the receiver was concerned, where the outlet was located, because practically all the moisture in the air would be carried along with it, and out of the receiver in any case. It is a fact that there is a drain cock provided at the farther end of this receiver, and also while the man in charge perfunctorily opens the cock every few days there is no water there to be drawn off.

In Fig. 2 is shown a vertical air receiver connected to two steam-driven air compressors at lock 7, on the barge canal. The air enters near the top of the receiver and passes out to the distributing pipes near the bottom. There is little practical advantage shown by this arrangement over that of the horizontal receiver connected as in Fig. 1, and if the connections were reversed or otherwise arranged very little water would accumulate in the receiver in any case.

That there is moisture in the air, and carried along with it when leaving the receiver, is evident, as in case the air has passed through a quarter of a mile of pipe and has become cooled to normal temperature while still under full pressure in the pipes, water will be found; and with any suitable opportunity here provided for the water to collect, and with means for drawing it off, considerable quantities may be obtained.

When compressed air is at its highest pressure, and at its lowest temperature, its capacity for moisture is at the minimum, and cold compressed air, which is at the point of saturation, would pass for dry air when expanded to atmospheric pressure and reheated. It is for securing this desired condition of low temperature with high pressure that the aftercooler has its value in connection with the air receiver. While there is little or no deposition of moisture in the air receiver as generally used, with only hot air passing through it, the case is very different if the air is thoroughly cooled before the receiver is reached, the receiver then becoming a water collector.

An interesting and uptodate compressor plant, the designers of which have given evidence of recognizing and appreciating the things which are worth while in compressed-air practice, is that which has been installed at High Falls, Ulster county, N. Y., for the work of construction of the Rondout siphon in the Catskill extension of the New York City water supply. In the power house there are ten compressors, with a combined capacity of 24,000 cubic feet of free air per minute. One feature of this plant is the employment of aftercoolers for the entire system. For each pair of compressors there is the usual air receiver. Conveniently near, but close to each vertical air receiver there is also a vertical aftercooler,

through which the air from the compressors must first pass and be thoroughly cooled before entering the receiver. In this case we can fully understand that the air in the receivers will be in condition to drop its superfluous moisture, and there can be little doubt that considerable quantities of water will be drawn from those receivers, and that the air when it comes to be used will be so "dry" that no inconveniences will later accompany its use.

I have to confess, however, that even the arrangement of the aftercoolers thus combined with and preceding the receivers does not promise complete success in the drying of the air. In the receivers here spoken of there would certainly be opportunity for discussion as to the best points of location for both inlet and outlet, but more than that is required to be considered.

To induce the air to drop as much of its moisture as possible, not only must we have the highest pressure and the lowest temperature occurring simultaneously, but we must also give the air *time* for the completion of the deposition of the released moisture.

I was at one time foreman of a shop extensively manufacturing pulleys, shafting, hangers, etc., especially pulleys, and I introduced a machine for grinding the faces of the pulleys instead of turning them. Of course the grinder made lots of dust which was effectively taken care of, so far as the machine was concerned, by an exhaust fan which was an integral part of the apparatus, but the disposal of the dust-laden air was a problem.

It happened that the proprietor of the works was often afflicted with novel and brilliant ideas, and one of them struck him in this connection. The tall brick boiler stack of the works was only a few feet from the grinder, and a pipe carrying the discharge from the fan was led into it, sending all the dust up into the sky with the smoke. Could anything be simpler? Unfortunately many people lived in the immediate neighborhood and on the first washday the dust was heard from. The white clothes on the lines were covered with yellow spots of iron rust, and the exhaust into the stack had to be suddenly abandoned.

We then went through a course of experimenting to find some way of getting the dust out of the air so that it would not make trouble. The exhaust pipe of the fan was only 3 inches in diameter, and we made a vertical box a foot square and of considerable height with shelves occupying half the area, about a foot apart vertically and placed alternately on opposite sides of the box, so that the air could zig-zag back and forth and deposit the dust on the shelves; which it didn't do to any extent. The same box was tried in a horizontal position with no better results, and other trials, of which these may be taken as typical, were no better.

FIG. 2.

The ultimate solution was simple enough. We finally realized that if the air moved slowly enough, the dust, or most of it, would drop through the air of its own weight and settle along the way. The air was discharged into one end of a horizontal box or chamber 4 feet square, and here it dropped the dust so that it could be shoveled out at openings provided, while the air passed out through a large opening near the top at the other end and was never after heard of.

The moisture in air, being always present, is, we might say, a part of the air, and until the point of saturation is reached the air remains transparent, and it is more ready to absorb more moisture as it finds the opportunity than it is to give it off. When its moisture capacity is so reduced by changes of pressure or temperature, especially the latter, as to cause it to be oversaturated, then the excess of moisture is condensed into water and forms a cloud distributed through the air, the cloud consisting of minute drops or particles of actual water, those portions of water being then heavier than the air and being sustained in the air just as dust is by friction, and with always a tendency to descend through the body of air by the action of gravity. Give the water in the air sufficient time, and it will drop to the bottom of the channel or pipe through which the air flows, when it can be drawn off.

In the air receiver as usually installed even if all the other conditions for drying the air are secured, there usually is not enough time allowed for the released water to drop out. It would seem that if the cost of the receiver, the aftercooler being assumed, was all put instead into the enlargement of sufficient lengths of horizontal pipe, at the beginning of the line thus forming a long horizontal receiver through which the air could flow with the requisite slowness, drier air would be delivered.—*Power and the Engineer.*

THE WATER WE BUY AND EAT

The following is the percentage of water in some of the familiar articles of food:

Uncooked beef or mutton	75
Lamb	64
Pork	50 to 60
Smoked bacon	22
The flesh of pigeons	70
Fowls and Ducks	70
A fat goose	38
Fish range from	40 to 80
Milk fresh from the can	86 to 88
Apples	80 to 82
Strawberries	90
Grapes	80
Turnips	90
Cabbages	90

Cucumbers, vegetable marrows and pumpkins are 95 per cent. water, or contain not more than half the solid matter found in milk.

A MOVABLE CAISSON FOR SUBMARINE WORK

BY THE GERMAN CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

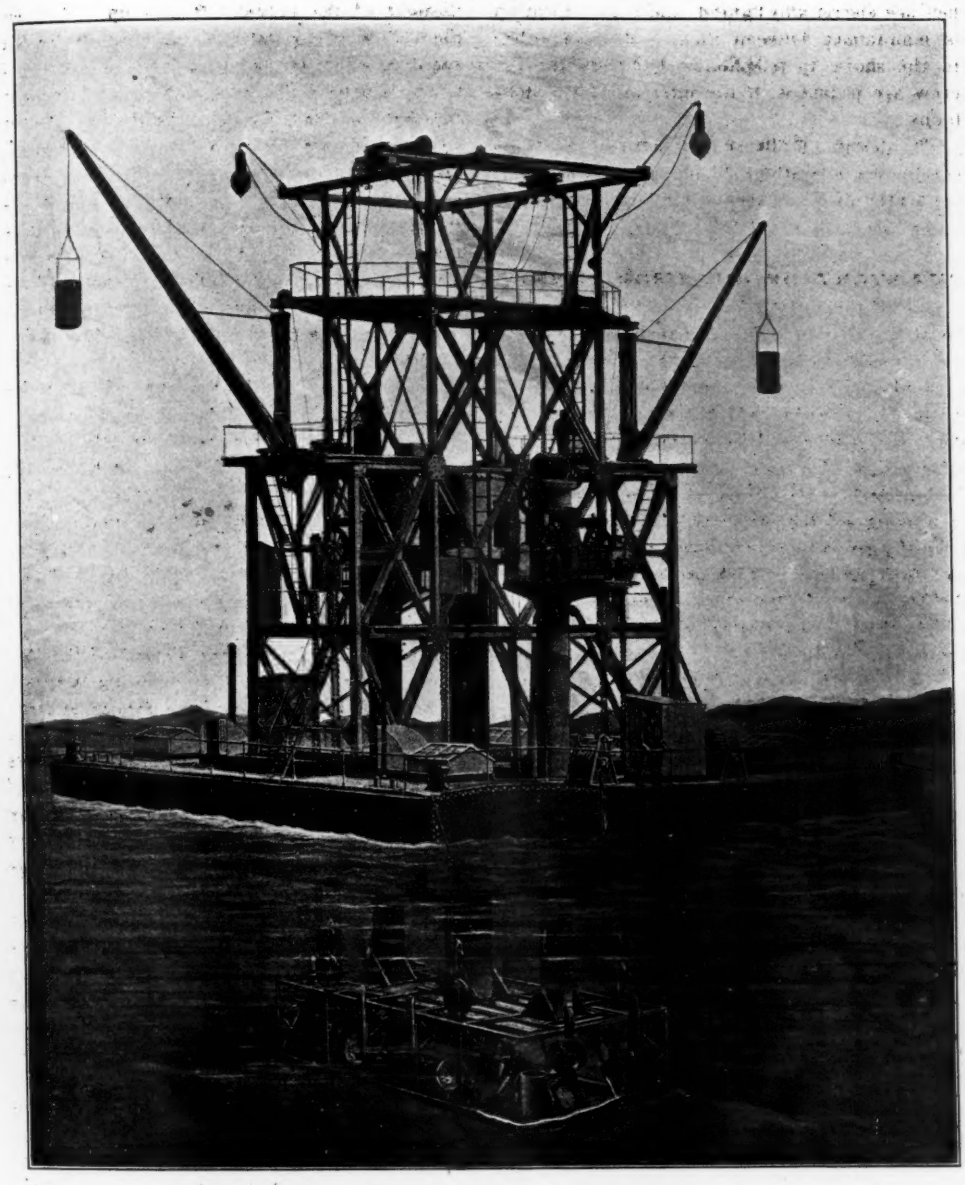
A remarkable diving bell or portable caisson has recently been constructed for the German Navy Department for use in the deepening of the harbor of its naval base at Tsingtau. The remarkable features are not so much those of the bell itself, but of its connection with the imposing structure above water shown in the half-tone, the whole making a complete and self-contained unit for excavating to a maximum depth of 15 meters (49 ft) below water level.

Two pontoons, each 54 feet long, 18 ft wide, and 7.2 ft. deep, are rigidly braced together bow and stern, forming between them a well up into which the diving bell may be completely withdrawn from the water. Upon the deck of the joined pontoons is erected the superstructure, from which the diving bell is suspended and operated, consisting principally of conventional I-beams and angles.

The diving bell is built of sheet iron, externally braced, and is 33 ft. long, 16 ft. wide, and 8.2 ft. high. Extending upward from the top of it are three telescopic shafts, two for the hoisting of the excavated material, each 31.5 in. in diameter, through which a bucket of 1 ton capacity can pass, and one of 39 in. diameter for the workmen. Each of these is provided with such an "air lock" as is now familiar in connection with tunnel and foundation work in New York and elsewhere, in which, as workmen enter, the air pressure is gradually raised from that of the atmosphere to that required to exclude water and mud from the interior of the caisson, being similarly reduced for those ascending from work. The air locks of the spoil shafts are identical, but the air may be compressed or exhausted much more rapidly in the hoisting of buckets of excavated material, the gradual change of pressure being necessary in the case of men only as a precaution against caisson disease.

The bell is suspended by four sets of chain tackle, one at each corner, which are mounted on opposite ends of two shafts on the operating platform of the superstructure, driven simultaneously by an electric motor when it is desired to raise or lower the bell.

Higher platforms carry two cranes, which receive the buckets of excavated material from



EXCAVATING APPARATUS WITH PORTABLE CAISSON.

the top of the spoil shafts and deliver them into scows, alongside or however desired, the cranes also being electrically driven, as are the winches inside the spoil shaft for hoisting the buckets from the interior of the bell. One man on the platform at the top of each of the latter can hoist the bucket with the winch, detach it, hook it onto the crane, and *vice versa*, and also raise and lower the bell as desired. Two more operators for the cranes above are required.

On the deck are three compressors supplying the necessary air pressure to the interior of the bell, electric power for the whole equipment being supplied from a stationary plant on shore. Both the superstructure and the interior of the

bell are electrically lighted, and communication is maintained between them and from either to the shore by telephone. Quarters for the crew are provided in the interior of the pontoons.

The design of the superstructure permits of continuous operations being carried on independently of the varying height of the pontoons due to rise and fall of tides.

THE STORY OF GUNNISON TUNNEL

One of the latest of the world's great beneficent, yet strictly business, enterprises owing its inception and completion to the agency of compressed air is the Gunnison tunnel in Southwestern Colorado, which before these lines greet the reader will have begun its career of reclamation of a vast acreage of "a land that God forgot." It will lead a river through a mountain, and the waters will transform a region of 200,000 to 300,000 acres of volcanic dust into farming land of high productivity. This is the foremost of thirty-two irrigation projects which the United States government has at present in hand.

The story of the inception of this vast enterprise and the carrying it to completion is told in a recent issue of the New York *Times* in an article typical of the excellent work which is being done by the great dailies of the Metropolis. What follows is mostly an abstract of the article referred to, and it is much to be regretted that the personality of the author is not revealed.

The Uncompahgre River, which gives its name to the valley also, has its source in the everlasting snows of Mount Wilson, fifty or sixty miles to the south, and flows into the Grand Canon of the Colorado forty miles to the northwest beyond the prosperous town of Grand Junction. The river does duty all along its course in irrigating the adjoining land, but its volume of water is not sufficient for the needs of more than a small fraction of the entire valley.

Many years ago one of the oldest settlers of the valley, John Hammond, while hunting up over the divide, where he could look far down, thousands of feet, into the Canon of the Gunnison, found himself wishing that he had that mass of water over on his land in the Uncompahgre Valley. The thought stayed with him. He told his neighbors, and wrote to the Denver papers about it. To him first came the thought of the tunnel. Riding up and down the valley, going out Fall and Spring for his supplies, wherever he could find any one to listen to him he delivered his incessant argument for the Gunnison Tunnel. As the years went by other people took up the same argumem, and in time it came to be one of the local issues of the western part of Colorado, and Hammond was sent to the Legislature as its proponent. He wasted no time and succeeded to the extent of passing a bill appropriating $25,000 for his beloved project. This, of course, was a mere bagatelle, about enough to make it a joke.

But in time the little group of irrigating Congressmen in Washington grew stronger until their caucus developed strength enough, with the powerful aid of President Roosevelt, to dictate the passage of the Reclamation Act of 1902. Now Hammond's chance really came. Through his Senators and Congressmen, and by personal letter, and through the combined efforts of the whole region, the Government was petitioned to take up the project.

One day Chief Engineer Newell of the Reclamation Service sent the following telegram to the resident engineer of the service at Denver: "Advise me if it is feasible to construct a tunnel under Vernal Mesa to carry the waters of Gunnison River to Uncompahgre Valley." With this the great undertaking began, so far as the Government was concerned. It meant that a survey must be made of the huge Black Canon of the Gunnison, through which no human being had ever gone. None but birds had crossed it; no living thing had ever come from its yawning depths to tell what was within. For many miles the waters of the Gunnison, beaten to foam, went roaring, 3,000 feet deep down in the earth through a narrow channel less than 100 feet wide.

There is seldom greater bravery shown than was displayed by the two civil engineers of the Reclamation Service who undertook to make the survey of the Black Canon. These were Mr. A. L. Fellows, the resident engineer, and Mr. W. W. Torrence, the assistant engineer. Climbing up over the Mesa, they made ready to descend 2,500 feet over the rock walls to the surface of the stream. In many places the descent was a sheer precipice, and they had to let themselves down by ropes. They carried only a rubber mattress, six days' food, scantily measured for the work they had to do, and

their surveying instruments. For twelve days they lived down in that huge chasm, where the light of the sun came but dimly for a few hours of the twenty-four, and never shone with unobstructed sunlight except at a few places in line with the meridian north and south.

Only here and there were there rocks or anything like a footing to stand on. Most of the time they were traveling in the water clinging to slippery rocks, swimming rapids, and forever in fear of the treachery of the merciless stream. Hardly a place was found at nightfall where they might go shivering to sleep. Their food was soon wet and spoiled, and it became a gnawing question whether they would get out alive. They lost their instruments and most of their clothes. Most of their journey through the canon was made by swimming in the cold waters of the Gunnison, but through it all they were mindful more of the great work that had been intrusted to them than they were of their personal comfort or even their lives. They made the observations and took the notes they were sent to get, and these were about all they brought out with them when at the end of twelve days they emerged at the mouth of Devil's Slide almost naked, worn out in body and mind, and pale and sick with hunger. The first thing they did was to make haste to the nearest telegraph office and send a short telegram of five words to Chief Newell in Washington: "The Gunnison tunnel is feasible."

After Fellows and Torrence made their survey and reached their eternally famous decision that the Gunnison tunnel was feasible, it was not long before orders went out from Washington to dig. This was in 1905. The tunnel was begun, one end in the gorge and the other from the edge of the valley. Miles of road had to be built to carry in machinery and supplies for the work. On the 6th of July, 1909, the shifts of men at work in each end section of the tunnel heard the last round of shots that broke the last remaining rock, and the two ends met.

So accurate were the surveys that the sides of the tunnel met within 12-100 of a foot and the top within 65-100 of a foot. The tunnel itself is six miles long; its cross-section is 10 feet 6 inches by 11 feet 6 inches and its capacity is 1,300 cubic feet of water per second. Its entire length is lined with cement, and at the outlet on the valley side it connects with a ditch twelve miles long, wider and deeper than the Erie Canal. This canal carries the entire volume of the Gunnison River taken for irrigation, winding around the adobe hills, gradually down to the level of the valley, to be distributed through a grand system of canals over a distance of forty miles.

In the four years it took to blast out the Gunnison tunnel many thrilling experiences came to the men engaged in the work. It was a long and tireless task, boring through the eternal fastnesses of that huge mountain. For the most part the rock is volcanic in character of the Archaic period, tough and obdurate. Yet there were adventures along the route. A few times there were lucky finds in the way of nuggets of gold. Several times they encountered streams of hot water, but more often streams of cold water, some of them highly mineral in character. Sometimes following the heavy blasts millions of gallons of water rushed in upon the workmen, who had to battle for their lives. Near the valley end of the tunnel an old ocean bed was found, and in the rock counless numbers of sea shells of different sizes. Through this rock the work was very dangerous and required constant timbering. In the Spring of 1905 the drills ran into an underground stream which caused a cave-in, and for forty-eight hours a number of workmen were buried alive. A shaft was sunk from the outside and the men were saved. Numbers of men that were caught in the cave-in were pinned down by rocks, but those who were free to work had shoveled up dikes to keep the water away from their injured comrades, and thus saved their lives.

There is very little Government land in the Uncompahgre Valley that will be available for homesteads when the water reaches it. Of the 150,000 acres that will be immediately under water about 15,000 are still in the public domain, withdrawn from entry. The rest is deeded land, most of it easily put under cultivation. Lands now under cultivation are worth anywhere from $35 to $50 an acre. This is land with some water, but not enough. There are many thousands of acres in the valley planted to prosperous orchards. The soil and the air of the region have precisely the virtues that give fruits of all kinds fine flavor and beautiful color. The fruit pours out of the valley in the Fall by hundreds of carloads, and in some years' competition for its purchase is so great

that Colorado enjoys but little of it, most of it going to Chicago and the East. Of this fine, rich land, whose soil is practically unlimited in depth, the average farmer needs but little. Forty acres is a large farm; twenty acres is sufficient for the average husbandman. Besides fruit, the farmer can get rich on alfalfa, which he can cut three times in a season and which yields him from five to seven tons altogether. Vegetables of every description grow to perfection. The finest strawberries are easily raised under irrigation. Sugar beets and potatoes, wheat, oats, and rye are easily raised. The altitude is from 5,000 to 6,000 feet, and corn is not entirely at home, but that does not matter where alfafa can be produced so abundantly. It is a land where dairying may easily be developed, and with the abundant alfafa bloom the busy bee can make mountains of honey.

The source whence the Gunnison derives its volume of water is the snowclad summits of the mountains. The watershed area embraces 3,850 square miles, and the estimated "run-off" of the watershed is 1,500,000 acre-feet. The rainfall over the valley annually is from six to twelve inches, and over the watershed from seven to twenty inches. The average size of the farms under this project will be about forty acres. Of the entire area it is estimated that 60,000 acres are available as first-class soil for apples and peaches. There are now orchards in the valley producing as high as $500 per acre net per annum. The alfalfa farmers, who will have about 80,000 in the bottom land, will not reap so great a return, but they will make as much as $60 to $80 per acre from either alfalfa or sugar beets, and can do even better with potatoes. The great beauty of the soil of the region is that it seems to be very happily balanced in plant food, with just the right proportion of potash, phosphate, and nitrogen. Very few weeds are to be encountered because the region has been a dry one, and the vegetation exceedingly sparse hitherto. It will be several years, however, before the entire region is gradually brought under water, as the system of main canals in the distributing district calls for 180 miles of canal digging. Of the thirty-two irrigation projects undertaken by the Government the Gunnison Tunnel is perhaps the most marvelous and in results it will doubtless measure up with the largest.

CHARGING AIR CHAMBERS OF PUMPING ENGINES

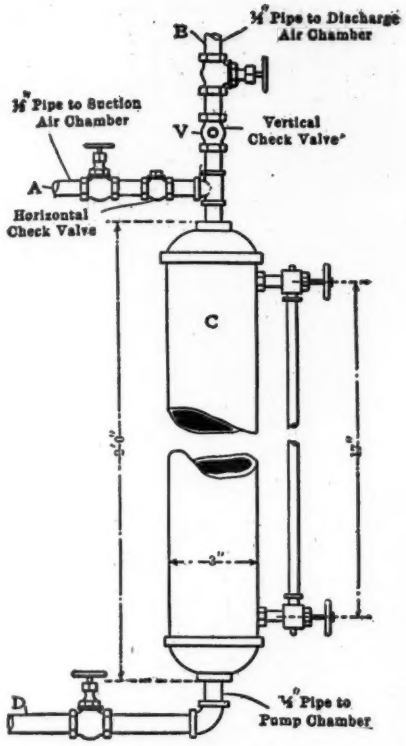
In operating pumping engines it is generally necessary to provide means of supplying air under pressure to the air chambers, particularly those on the discharge pipes, as, through leaks in the piping or by absorption or entrainment in the rapidly moving water, the air gets away and must be replaced if the pump is to work smoothly.

It is generally customary to provide an air compressor of some kind; many plants use the direct-acting air-brake type, which is very compact and convenient. When the water is taken from a well or a pond, by a pump located considerably above the surface of the water, advantage may be taken of the fact that the pressure in the pump chamber of a reciprocating pump is alternately above and below the atmospheric line to employ what is sometimes called a snifting valve, in which on the suction stroke the air is drawn into a cylinder connected by a pipe with the pump chamber, and on the discharge stroke is forced through a pipe into the air chamber, check valves on the air-suction and discharge pipes preventing the entrapped air from getting back through the suction pipe on the discharge stroke, or returning from the air chamber on the suction stroke.

In a small pumping station the water comes to the pump from a supply main serving at a pressure of about 25 pounds and is discharged by the pump against a pressure of about 145 pounds per square inch, in order to supply an elevated part of the town.

On account of the high pressure in the discharge pipe it was found very difficult to supply air to the discharge air chamber with the single-stage air compressor in use at this plant as the slightest wearing away of the piston or valves rendered the compressor useless. As the cost of a new two-stage compressor, or of adding an extra cylinder to the old machine, was considerable, a special form of snifting valve was devised which takes its air supply from a large air tank in the basement, connected to the suction main and used as a shock absorber.

As the air pressure in this tank is only 25 pounds, the single-stage compressor will put air into it with ease. An air pipe runs from the top of this tank to the suction check valve



on the snifting device attached to the water end of the pump. At an elevation of about 14 feet above the water level in the suction tank the pressure due to a column of water of this height is thus available to force the air into the snifter. The sketch shows the construction of the device, which is operated as follows:

Air from the suction tank enters at *A*, on the suction stroke, displacing the water in the cylinder *C* and forcing it into the pump chamber through the pipe *D*. On the discharge stroke, water, under 145 pounds pressure from the pump chamber, rushes into the cylinder and forces the air through the vertical check valve at *V* into the discharge air chamber.

The snifter was made at trifling expense out of an old cast-iron water column taken from an abandoned boiler. It has worked in a perfectly satisfactory manner for about a year with a considerable saving in expense and annoyance.

Experiments have been made which show that with a properly proportioned inspirator, using the high-pressure water, it is possible to draw air into the suction tank, thus dispensing entirely with the steam-operated air compressor, but as the experimental inspirator was too small to use in practice the compressor is still in service.—*Power and the Engineer.*

VOLUMES, PRESSURES AND TEMPERATURES IN THE ADIABATIC COMPRESSION OF AIR

By Frank Richards.

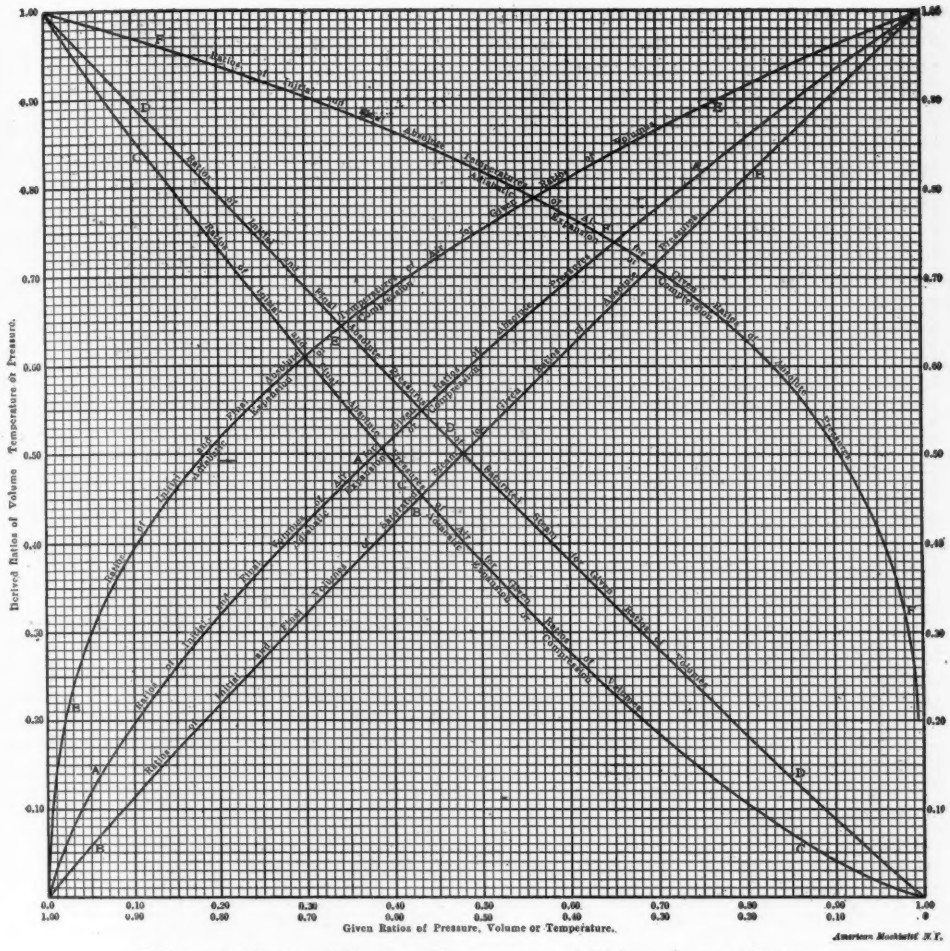
The table and chart herewith should be of service to the large and constantly increasing number of workers and investigators in mechanical lines who have to do with compressed air. The actual compression of air in the usual way, in cylinders having reciprocating pistons, is practically adiabatic in each specific case, and in investigating the power requirements, the actual power consumption and other conditions of such compression, it is necessary always to know and consider the pressures, volumes and temperatures involved, and for this work the table and chart here presented should prove a substantial aid.

On a little inspection of the table and diagram it will be seen that if we trace the ratio of the initial to the terminal (or *vice versa*) of either the pressures, the volumes or the temperatures of air, compressed and delivered without loss or gain of heat (adiabatic compression), the ratios of the other two particulars are easily determined, and then having the ratio in either case, with the pressure, volume, or temperature at either the beginning or the termination of the act of compression (or expansion), the corresponding pressure, volume or temperature for the other end of the operation also will be known.

Our first and most easily accessible knowledge of any specific operation of compression is as to the pressures at the beginning and at the end of the compression. Thus, say that we are working at or near sea level, or taking in the air at an absolute pressure of 14.7 pounds and delivering the air at 80 pounds gage, the absolute pressure then, of course, being 80+14.7=94.7 pounds, the ratio of initial to terminal pressure will be 14.7÷94.7= 0.1552. With these pressures at the opposite ends of the stroke the ratio will, of course, be the same whether compressing the air in the ordinary reciprocating compressor or expanding the air in doing work in an air engine

Ratio.	Reciprocal.	A	Reciprocal.	B	Reciprocal.	C	Reciprocal.	D	Reciprocal.	E	Reciprocal.	F	Reciprocal.
0.01	100	0.0388	26.315	0.0131	76.259	0.0015	666.66	0.0075	133.33	0.1528	6.544	0.2633	3.799
0.02	50	0.0621	16.103	0.0252	39.682	0.0041	243.90	0.0157	63.69	0.2027	4.933	0.3219	3.106
0.03	33.33	0.0829	12.062	0.0369	27.102	0.0072	138.88	0.0241	41.49	0.2392	4.180	0.3620	2.762
0.04	25	0.1017	9.832	0.0483	20.704	0.0108	92.592	0.0327	30.58	0.2689	3.718	0.3935	2.541
0.05	20	0.1191	8.396	0.0596	16.778	0.0147	68.027	0.0414	24.15	0.2946	3.394	0.4198	2.382
0.06	16.66	0.1356	7.374	0.0708	14.039	0.0190	52.631	0.0503	19.88	0.3173	3.151	0.4425	2.259
0.07	14.28	0.1513	6.609	0.0819	12.210	0.0237	42.194	0.0593	16.86	0.3379	2.959	0.4627	2.161
0.08	12.5	0.1663	6.013	0.0928	10.775	0.0286	34.964	0.0683	14.64	0.3568	2.803	0.4810	2.079
0.09	11.11	0.1808	5.531	0.1037	9.643	0.0337	29.675	0.0774	12.92	0.3744	2.671	0.4977	2.009
0.10	10	0.1949	5.131	0.1145	8.733	0.0391	25.575	0.0866	11.54	0.3908	2.558	0.5131	1.948
0.11	9.091	0.2085	4.796	0.1253	7.981	0.0447	22.371	0.0958	10.43	0.4063	2.461	0.5275	1.895
0.12	8.333	0.2218	4.508	0.1359	7.358	0.0505	19.802	0.1051	9.522	0.4210	2.375	0.5410	1.848
0.13	7.692	0.2348	4.259	0.1466	6.821	0.0566	17.668	0.1144	8.741	0.4350	2.298	0.5537	1.806
0.14	7.143	0.2475	4.040	0.1572	6.361	0.0628	15.923	0.1238	8.077	0.4484	2.230	0.5657	1.767
0.15	6.667	0.2599	3.847	0.1677	5.963	0.0692	14.451	0.1332	7.507	0.4612	2.168	0.5771	1.732
0.16	6.25	0.2721	3.675	0.1782	5.611	0.0758	13.192	0.1427	7.007	0.4735	2.112	0.5880	1.700
0.17	5.882	0.2841	3.519	0.1887	5.299	0.0825	12.121	0.1522	6.570	0.4853	2.060	0.5984	1.671
0.18	5.556	0.2959	3.380	0.1991	5.022	0.0894	11.185	0.1617	6.188	0.4968	2.012	0.6084	1.643
0.19	5.263	0.3074	3.253	0.2095	4.773	0.0965	10.362	0.1713	5.837	0.5079	1.968	0.6180	1.618
0.20	5	0.3188	3.136	0.2199	4.547	0.1037	9.643	0.1809	5.527	0.5186	1.930	0.6273	1.594
0.21	4.762	0.3301	3.029	0.2302	4.344	0.1111	9.001	0.1905	5.249	0.5290	1.890	0.6362	1.571
0.22	4.545	0.3412	2.930	0.2405	4.157	0.1186	8.431	0.2001	4.997	0.5392	1.854	0.6448	1.551
0.23	4.348	0.3521	2.840	0.2508	3.987	0.1263	7.917	0.2098	4.766	0.5490	1.821	0.6532	1.530
0.24	4.167	0.3629	2.755	0.2610	3.831	0.1341	7.457	0.2195	4.555	0.5586	1.792	0.6613	1.512
0.25	4	0.3736	2.676	0.2712	3.687	0.1420	7.042	0.2293	4.361	0.5680	1.760	0.6692	1.494
0.26	3.846	0.3841	2.603	0.2814	3.553	0.1501	6.662	0.2390	4.182	0.5772	1.732	0.6768	1.477
0.27	3.704	0.3946	2.534	0.2916	3.429	0.1583	6.317	0.2488	4.019	0.5861	1.706	0.6843	1.461
0.28	3.571	0.4049	2.469	0.3018	3.313	0.1666	6.000	0.2586	3.867	0.5949	1.681	0.6915	1.446
0.29	3.448	0.4151	2.409	0.3119	3.206	0.1750	5.701	0.2684	3.725	0.6035	1.657	0.6986	1.431
0.30	3.333	0.4252	2.351	0.3220	3.105	0.1836	5.446	0.2783	3.593	0.6119	1.634	0.7055	1.417
0.31	3.226	0.4353	2.297	0.3321	3.011	0.1922	5.203	0.2881	3.471	0.6201	1.611	0.7122	1.404
0.32	3.125	0.4452	2.246	0.3422	2.922	0.2010	4.975	0.2980	3.355	0.6282	1.591	0.7188	1.391
0.33	3.03	0.4550	2.197	0.3522	2.839	0.2099	4.764	0.3079	3.247	0.6361	1.572	0.7252	1.378
0.34	2.941	0.4646	2.151	0.3623	2.760	0.2189	4.568	0.3178	3.146	0.6439	1.553	0.7315	1.365
0.35	2.857	0.4744	2.108	0.3723	2.686	0.2281	4.384	0.3278	3.050	0.6516	1.534	0.7377	1.355
0.36	2.778	0.4840	2.066	0.3823	2.615	0.2373	4.214	0.3377	2.961	0.6591	1.517	0.7438	1.344
0.37	2.703	0.4935	2.026	0.3923	2.549	0.2466	4.055	0.3477	2.876	0.6665	1.500	0.7497	1.333
0.38	2.632	0.5030	1.988	0.4023	2.485	0.2561	3.904	0.3577	2.795	0.6738	1.484	0.7555	1.323
0.39	2.564	0.5124	1.949	0.4122	2.426	0.2656	3.765	0.3677	2.719	0.6810	1.468	0.7612	1.313
0.40	2.5	0.5216	1.917	0.4222	2.368	0.2752	3.633	0.3777	2.647	0.6881	1.453	0.7668	1.304
0.41	2.439	0.5309	1.883	0.4321	2.314	0.2850	3.509	0.3878	2.578	0.6951	1.438	0.7723	1.294
0.42	2.381	0.5400	1.851	0.4420	2.262	0.2948	3.392	0.3978	2.513	0.7019	1.424	0.7777	1.285
0.43	2.326	0.5491	1.819	0.4519	2.212	0.3047	3.281	0.4079	2.451	0.7087	1.411	0.7831	1.276
0.44	2.273	0.5582	1.791	0.4618	2.165	0.3148	3.176	0.4180	2.392	0.7154	1.397	0.7883	1.268
0.45	2.222	0.5672	1.763	0.4716	2.122	0.3249	3.084	0.4281	2.336	0.7220	1.385	0.7934	1.260
0.46	2.174	0.5761	1.735	0.4815	2.076	0.3351	2.984	0.4382	2.282	0.7285	1.372	0.7985	1.252
0.47	2.128	0.5850	1.709	0.4913	2.035	0.3454	2.895	0.4483	2.230	0.7349	1.360	0.8035	1.244
0.48	2.083	0.5938	1.684	0.5012	1.979	0.3558	2.810	0.4585	2.181	0.7412	1.349	0.8084	1.237
0.49	2.041	0.6025	1.659	0.5110	1.957	0.3663	2.730	0.4686	2.134	0.7475	1.337	0.8133	1.229
0.50	2	0.6112	1.636	0.5208	1.920	0.3768	2.654	0.4788	2.091	0.7537	1.326	0.8180	1.222
0.51	1.961	0.6199	1.613	0.5306	1.884	0.3875	2.581	0.4890	2.045	0.7598	1.316	0.8227	1.215
0.52	1.923	0.6285	1.591	0.5404	1.850	0.3982	2.511	0.4992	2.003	0.7658	1.305	0.8274	1.208
0.53	1.887	0.6371	1.569	0.5502	1.817	0.4091	2.444	0.5094	1.963	0.7718	1.295	0.8320	1.201
0.54	1.852	0.6456	1.549	0.5599	1.786	0.4200	2.381	0.5196	1.924	0.7777	1.285	0.8365	1.195
0.55	1.818	0.6540	1.529	0.5697	1.755	0.4310	2.320	0.5298	1.887	0.7836	1.276	0.8409	1.189
0.56	1.785	0.6625	1.509	0.5794	1.725	0.4420	2.262	0.5401	1.851	0.7893	1.266	0.8453	1.183
0.57	1.754	0.6708	1.491	0.5892	1.697	0.4532	2.206	0.5503	1.817	0.7951	1.257	0.8497	1.177
0.58	1.724	0.6792	1.472	0.5989	1.669	0.4644	2.153	0.5606	1.783	0.8007	1.248	0.8540	1.171
0.59	1.695	0.6875	1.454	0.6086	1.643	0.4757	2.102	0.5709	1.751	0.8063	1.240	0.8582	1.165
0.60	1.667	0.6957	1.437	0.6183	1.613	0.4871	2.051	0.5812	1.720	0.8119	1.231	0.8624	1.159
0.61	1.639	0.7039	1.420	0.6280	1.592	0.4986	2.005	0.5914	1.691	0.8174	1.223	0.8666	1.153
0.62	1.613	0.7121	1.404	0.6377	1.568	0.5101	1.960	0.6018	1.661	0.8228	1.215	0.8708	1.148
0.63	1.587	0.7203	1.388	0.6474	1.544	0.5218	1.910	0.6121	1.633	0.8282	1.207	0.8747	1.143
0.64	1.563	0.7284	1.372	0.6570	1.522	0.5335	1.874	0.6224	1.606	0.8335	1.199	0.8787	1.138
0.65	1.538	0.7364	1.358	0.6667	1.500	0.5452	1.835	0.6327	1.580	0.8388	1.192	0.8827	1.132
0.66	1.515	0.7445	1.343	0.6763	1.478	0.5571	1.795	0.6431	1.554	0.8441	1.184	0.8866	1.128
0.67	1.493	0.7524	1.328	0.6860	1.457	0.5690	1.757	0.6534	1.530	0.8493	1.177	0.8904	1.123
0.68	1.471	0.7604	1.315	0.6956	1.437	0.5810	1.721	0.6638	1.506	0.8544	1.170	0.8943	1.118
0.69	1.449	0.7683	1.301	0.7052	1.418	0.5931	1.686	0.6742	1.483	0.8595	1.163	0.8981	1.113
0.70	1.429	0.7762	1.288	0.7148	1.399	0.6052	1.652	0.6846	1.461	0.8646	1.156	0.9018	1.108
0.71	1.408	0.7841	1.275	0.7245	1.380	0.6174	1.619	0.6950	1.438	0.8696	1.149	0.9055	1.104
0.72	1.389	0.7919	1.263	0.7341	1.359	0.6297	1.588	0.7054	1.417	0.8746	1.143	0.9092	1.099
0.73	1.370	0.7997	1.250	0.7436	1.344	0.6420	1.557	0.7158	1.397	0.8795	1.137	0.9128	1.095
0.74	1.351	0.8075	1.238	0.7532	1.327	0.6545	1.527	0.7262	1.375	0.8844	1.130	0.9165	1.091
0.75	1.333	0.8152	1.227	0.7628	1.311	0.6669	1.499	0.7366	1.357	0.8893	1.124	0.9200	1.087
0.76	1.316	0.8229	1.215	0.7724	1.294	0.6795	1.471	0.7471	1.338	0.8941	1.118	0.9236	1.082
0.77	1.299	0.8306	1.204	0.7819	1.278	0.6921	1.444	0.7575	1.321	0.8989	1.112	0.9271	1.078
0.78	1.282	0.8382	1.193	0.7915	1.263	0.7048	1.418	0.7680	1.302	0.9036	1.106	0.9305	1.074
0.79	1.266	0.8459	1.182	0.8010	1.248	0.7176	1.393	0.7785	1.284	0.9083	1.100	0.9340	1.070
0.80	1.25	0.8534	1.171	0.8106	1.233	0.7304	1.369	0.7889	1.267	0.9130	1.095	0.9374	1.066
0.81	1.235	0.8610	1.161	0.8201	1.219	0.7433	1.345	0.7994	1.251	0.9176	1.089	0.9408	1.062
0.82	1.22	0.8685	1.151	0.8296	1.205	0.7562	1.322	0.8099	1.234	0.9222	1.084	0.9441	1.059
0.83	1.205	0.8761	1.140	0.8392	1.191	0.7692	1.300	0.8204	1.219	0.9268	1.079	0.9474	1.055
0.84	1.19	0.8835	1.131	0.8487	1.178	0.7823	1.278	0.8309	1.203	0.9313	1.073	0.9507	1.051
0.85	1.176	0.8910	1.122	0.8582	1.165	0.7955	1.257	0.8414	1.188	0.9358	1.068	0.9540	1.048
0.86	1.163	0.8984	1.113	0.8678	1.152	0.8087	1.236	0.8519	1.173	0.9403	1.063	0.9572	1.044
0.87	1.149	0.9058	1.104	0.8772	1.139	0.8220	1.216	0.8625	1.159	0.9448	1.058	0.9605	1.041
0.88	1.136	0.9132	1.095	0.8866	1.127	0.8353	1.197	0.8730	1.145	0.9492	1.053	0.9636	1.037
0.89	1.124	0.9206	1.086	0.8961	1.115	0.8487	1.178	0.8835	1.131	0.9536	1.048	0.9668	1.034
0.90	1.111	0.9279	1.077	0.9056	1.104	0.8621	1.159	0.8941	1.118	0.9579	1.043	0.9699	1.031
0.91	1.099	0.9352	1.069	0.9151	1.093	0.8757	1.142	0.9047	1.105	0.9623	1.039	0.9730	1.027
0.92	1.087	0.9425	1.061	0.9245	1.081	0.8892	1.124	0.9152	1.092	0.9666	1.034	0.9761	1.024
0.93	1.075	0.9498	1.052	0.9340	1.070	0.9029	1.107	0.9258	1.080	0.9708	1.030	0.9792	1.021
0.94	1.064	0.9570	1.045	0.9434	1.059	0.9166	1.091	0.9364	1.068	0.9751	1.025	0.9822	1.019
0.95	1.053	0.9642	1.037	0.9529	1.049	0.9303	1.074	0.9470	1.056	0.9793	1.021	0.9853	1.014
0.96	1.042	0.9714	1.029	0.9623	1.039	0.9441	1.059	0.9576	1.044	0.9835	1.016	0.9882	1.012
0.97	1.031	0.9786	1.021	0.9717	1.029	0.9580	1.043	0.9682	1.032	0.9877	1.012	0.9912	1.009
0.98	1.020	0.9858	1.014	0.9812	1.019	0.9720	1.029	0.9788	1.021	0.9918	1.008	0.9942	1.006
0.99	1.01	0.9929	1.007	0.9906	1.009	0.9860	1.014	0.9894	1.011	0.9959	1.004	0.9971	1.003
1.00	1.	1.	1	1.	1.	1.	1.	1.	1.	1	1.	1.	1.

TABLE OF RATIOS AND RECIPROCALS OF PRESSURE TEMPERATURE AND VOLUME IN THE ADIABATIC COMPRESSION OF AIR


Derived Ratios of Volume Temperature or Pressure.
Given Ratios of Pressure, Volume or Temperature.
American Machinist N.Y.

Relations of Ratios of Pressure, Temperature and Volume in the Adiabatic Compression of Air

Use of Chart

In the chart the given or known ratios, from which the desired results are to be obtained, are noted horizontally on the base line and the ratio desired is then indicated by the vertical distance from the base line at the point noted to the curve of ratios required in the particular case. The curves *A*, *B* and *E* start from the left-hand corner, and the curves *C*, *D* and *F* from the right-hand corner, the base line being figured for facility of reading in either direction.

Say that we have an air compressor working at an altitude of 2000 feet above sea level compressing 900 cubic feet of free air per minute and delivering it into the receiver at 75 pounds gage pressure. The normal atmospheric pressure at 2000 feet being, say, 1.37 pounds, and the absolute delivery pressure then being 75 + 13.7 = 88.7 pounds, the pressure ratio will be 13.7 ÷ 88.7 = 0.1544. To ascertain now the delivery volume of the air compressor, we take this rating, the first two figures of it as they stand and the other two figures by approximating, and locate it on the base line reading from the left-hand corner. Taking 15 spaces and a little less than a half of the next space we note the vertical distance from this point up to curve *A*, and this we find to be 26, and a little more than half of the next space, say, 26½, or, decimally, 0.2662, and this being the ratio of the terminal to the initial volume, the actual terminal volume per minute will be 900 × 0.2662 = 239.58 cubic feet.

The volume thus ascertained is, of course, the volume actually delivered and at the moment of delivery, assuming that the compression was perfectly adiabatic throughout, or that the body of air, while being compressed, neither lost nor gained any heat by conduction, radiation or otherwise, and as a matter of fact this is nearly the actual state of affairs in ordinary dry compression. If, during compression, the air could be maintained at constant temperature the ratios of volumes would then be practically the same as the ratios of pressures, and the "curve" for this would be a straight diagonal from the lower left-hand to the upper right-hand corner.

To ascertain now the ratio of temperatures as the result of our compression the operation is similar, except that in this case we use curve *F* instead of curve *A*. Taking our ratio of pressures 0.1544, with which we started, but this time reading from the right-hand corner, we find the vertical reading to curve *F* to be 0.58, or so little above this that the excess is negligible. We note in the table that the reciprocal of 0.58 is 1.724, and this it will be convenient to use here. If the initial temperature of the air was 60 degrees Fahrenheit, then the absolute initial temperature would be 60 + 461 = 521, and the terminal temperature would be 521 × 1.724 = 898 absolute, or 898 — 461 = 437 degrees Fahrenheit.

If we take our ratio of volumes 0.2662, as previously ascertained and reading from the left-hand corner note the vertical reading to curve *E*, the ratio of temperatures will be found to be the same as that obtained from curve *F*.

If we take any horizontal line of the chart, or any horizontal line arbitrarily placed upon the chart and note the points where curves *E* and *F* cross it, then the distance from curve *E* to the left-hand vertical boundary will be the ratio of volumes for that temperature ratio and the distance from curve *F* to the right-hand will be the ratio of pressures, so that all particulars embodied in curves *A* and *C* are really obtainable from curves *E* and *F*

or motor, only in one case the ratio as given would be the convenient multiplier in our computations and in the other case the reciprocal would apply, so that the reciprocal for every ratio is provided in the table as here given, for practical working purposes.

The table is not entirely new, the principal elements of it having been computed more than 30 years ago by Richard H. Buel and published with other valuable matter, in Appleton's "Cyclopedia of Applied Mechanics." The reciprocals of all the ratios have been added and the chart has been entirely plotted from the table, the smoothness of the curves in the plotting attesting the accuracy, or at least the consistency, of the figures.

The several curves of the chart are designated by the same letters as the columns of the table to which they correspond, adiabatic compression, or expansion, being assumed throughout. The several series of ratios, whether in the curves of the chart, or in the columns of the table are as follows:

A=Ratios of initial and terminal volumes of air for given ratios of absolute pressures.

B=Ratios of initial and terminal volumes of saturated steam for given ratios of absolute pressures.

C=Ratios of initial and terminal absolute pressures of air for given ratios of volumes.

D=Ratios of initial and terminal absolute pressures of saturated steam for given ratios of volumes.

E=Ratios of initial and terminal absolute temperatures of air for given ratios of volumes.

F=Ratios of initial and terminal absolute temperatures of air for given ratios of absolute pressures.

The formulas (from Rankine) by which the ratios in the several columns were computed are at the top of the next column, $\frac{1}{R}$ being the ratio in the first column of the table:

$$A \ldots\ldots \left(\frac{1}{R}\right)^{0.71}$$

$$B \ldots\ldots \left(\frac{1}{R}\right)^{\frac{10}{17}}$$

$$C \ldots\ldots \left(\frac{1}{R}\right)^{1.408}$$

$$D \ldots\ldots \left(\frac{1}{R}\right)^{\frac{17}{24}}$$

$$E \ldots\ldots \left(\frac{1}{R}\right)^{0.408}$$

$$F \ldots\ldots \left(\frac{1}{R}\right)^{0.29}$$

To anyone appreciating and capable of intelligently using the table, any explanation of methods of procedure would be superfluous. The table, although somewhat voluminous is essentially simple, as is also the chart which embodies it in every particular. As I would be glad to promote the use of the chart as a quick and handy means of obtaining closely approximate and reliable results, a single example of its manipulation is given under the chart on the preceding page.—*American Machinist.*

A SELF-STARTING GAS ENGINE

A four cycle internal combustion engine which is self starting without the aid of outside means is the invention of an engineer named Herman Dock. While compressed air is used, it is not its direct pressure upon the piston that effects the starting. The compressed air is forced through the carbureter to carry an explosive mixture into the manifold connecting the cylinders. Until actuated by the cam shaft the inlet valves remain seated under pressure due to the greater area of a balancing piston on the valve stem. After the start produced by exploding the compressed mixture the compressed air is cut off and the pressure in the manifold becomes again atmospheric. Thereupon the check valve opens and the engine operates in the ordinary way. A mechanical feature of the engine that is a departure is the connection of the piston and rod by a cup joint instead of the usual wrist pin. As a consequence the piston floats—that is, is free to rotate with respect to the axis of the rod, which has the effect of making the wear more uniform.

A suspension bridge with a clear span of 600 ft. has been constructed across the Culebra Cut on the Panama Canal, mainly to carry compressed air and water mains over the cut.

CAISSON DISEASE DISCUSSION

The valuable paper by Henry Japp, upon Caisson Disease and its Prevention, which in our September issue was reproduced in a condensed form from the Proceedings of the American Society of Civil Engineers, elicited interesting discussion upon its presentation before the Society. Taking the liberty of cutting where possible, the principal contributions to the discussion are here reproduced:

DR. J. S. HALDANE, F. R. S.—After very carefully reading Mr. Japp's paper, the writer considers it an extremely valuable contribution to a practical solution of the prevention of caisson disease. He clearly points out the difficulties involved in adopting without modification for all compressed-air work the plan of "stage decompression" worked out by Dr. Boycott, Lieutenant Damant, and the writer, which has been in successful use since 1907, for divers of the British Navy. A full account of the experimental evidence on which this plan is based will be found in the *Journal of Hygiene*, 1908, pp. 342-443. Most of the experiments were made at very high pressures, such as 75 lb., and they were carried out with a view to deep diving. Work in tunnels and caissons, however, is conducted at much lower pressures; practical experience is much more wide; and, thanks mainly to Mr. Moir, recompression is usually readily available. It becomes a question, therefore, whether the margin of safety which was allowed in decompression cannot be narrowed without appreciable danger. The new evidence which Mr. Japp has brought forward certainly seems to indicate that this is the case. He records the fact that in the construction of the East River Tunnels 330 "seasoned" men were employed for 36 days in two 3-hour shifts at a pressure of 40 lb., and were decompressed by a modified form of stage-decompression in 48 min., without a single serious case of caisson disease occurring. Thus there must have been about 24,000 individual decompressions without any mishap. Mr. Japp calculates that the maximum air-saturation left in any part of the bodies of these men at the end of decompression, corresponded to a pressure of 27 lb. In view of these results the author proposes to shorten stage-decompression in such a way that in place of the 19 lb. of residual saturation which the writer has proposed, 25 lb. should be left in the case of men who are "seasoned" to the work. This would greatly shorten stage-decompression, and render it a much more easily practicable process, although the pains in joints, etc., which are the most easily produced and the least serious symptoms of caisson disease, would not be prevented.

The reason for the proposed 19 lb. is that occasional serious cases seem to occur at working pressures down to 20 lb., and that a fatal case is recorded at 23 lb. On the other hand, there can be little doubt that for the great majority of men a pressure of 25 lb. would not cause appreciable danger.

Susceptible individuals can doubtless be excluded, to some extent, by a careful medical examination, with special regard to the state of the heart and blood vessels, and to any general debilitating cause, among which age must be included. Another very important factor is fatness. Dr. Boycott and Lieutenant Damant decompressed 70 guinea pigs at a dangerous rate after exposure to a pressure of 100 lb. Exactly half of the animals died of caisson disease, and the other half were killed. The percentage of fat was found to be much greater in those which had died of caisson disease. In consequence of these experiments, all British naval divers are now disqualified at the medical examinations from deep diving if they are inclined to fatness.

While a medical examination will probably exclude most of the more susceptible individuals, it still seems very doubtful whether all can be excluded in this way. With new men, therefore, it is desirable that preliminary trials should be made with short shifts. These men should be carefully watched after decompression, and promptly recompressed if they show any threatening symptom; and any man who has shown threatening symptoms should be rejected.

With these precautions, in addition to having a medical air-lock and keeping the men within reach of recompression for about an hour after they come out, the writer thinks that in all probability Mr. Japp's plan would prove successful.

The conditions vary so widely in different kinds of work in compressed air that it seems hardly desirable to lay down, by legislation or otherwise, any hard-and-fast general rules as to decompression. The writer, however, thinks

that for any particular undertaking in compressed air, special rules, suitable to the particular circumstances, should be drawn up and strictly enforced.

DR. FREDERICK L. KEAYS.—The three great factors in the causation of compressed-air illness are: The degree of pressure, the time under pressure, and the decompression period. The degree of pressure is, of course, the chief factor, and this is not a matter of choice, but depends on the depth to which the work must be carried. The only means of preventing illness, then, which are left to the engineer are the regulation of shifts and of decompression periods. In the past it has been thought that the longer one stays under pressure, the greater will be the dangers of compressed-air illness. This is true, up to a certain point, namely, that at which there is complete saturation of the blood and body fluids with the gases of the air.

The body fluids are practically saturated at any given pressure in about three hours. This belief is based on the results of the work in the Pennsylvania East River Tunnels. From a study of the records, it was found that men working for periods of less than 3 hours were less likely to have "bends," and much less likely to have a serious illness than those who worked for 3 hours or longer. Furthermore, it was found that in comparing the results of 6-hour shifts—which, since they were divided into two 3-hour periods with an interval of 3 hours at normal pressure, really meant 3 hours' exposure—with the results of 8-hour shifts, at almost equal pressures and with corresponding rates of decompression, there were fully as many cases of illness with the former shifts as with the latter, and certainly more serious and fatal cases. The real danger in compressed-air work comes with or after decompression. For this reason the practice, which has been almost universally followed, of dividing the working shift into two periods, is a bad one, for it doubles the number of decompressions. The results would be better in tunnel and caisson work, if continuous shifts of 4, 6, or 8 hours were arranged to suit the pressures; say, 4 hours for pressures of from 42 to 50 lb. +, 6 hours for pressures of from 32 to 42 lb. +, and 8 hours for pressures below 32 lb. +, and if the decompression periods were increased to reasonably safe lengths of time.

The question of the decompression period is a difficult one to settle. In the first place it must be admitted that certain men have individual susceptibility to the effects of compressed air. While one man may work even at a high pressure and decompress rapidly without any symptoms of illness, another, under even more favorable conditions of pressure, length of shift, and time of decompression, may succumb to sudden death from syncope and collapse, and the autopsy will show large quantities of free gas in the circulatory system. Among practical compressed-air workers there is a decided difference of opinion as to the necessary length of decompression periods, some even claiming that quick decompression is preferable. Nearly all men, however, who have dealt with the subject from the physiological and medical standpoint, have advocated fairly long times for decompression. The writer believes that lengthening the time of decompression is the most efficient means of reducing the number of cases of compressed-air illness, as well as the number of serious cases.

On account of the common occurrence of cases of delayed onset of symptoms, it is not believed that lengthening the decompression to periods claimed by Bert, von Schrötter, Hill, and Haldane, to be safe, would prevent all cases of illness, or even serious and fatal cases. A comparatively large number of men first begin to have symptoms of compressed-air illness several hours after decompression, in some cases after as many as 12 or 15 hours, and in a fairly large number, after 3 hours. In two fatal cases symptoms began to appear between 2 and 3 hours after decompression. Reasonably long decompression periods are, however, efficient in reducing the number of cases of illness, disability, and death.

Just what are reasonably safe lengths for decompression periods have never been determined. In the work on the Pennsylvania East River Tunnels after April, 1906, a rate of decompression of at least 1 min. for each 2-lb. pressure was required, and quite generally followed. This seemed to cause less illness and a reduction in the number of serious cases, as compared with previous months when there were no rules as to the rate of decompression. Even this rate of decompression, which was longer than has been required in any compressed-air work in the United

States, did not prevent serious and fatal cases. For this reason the writer thinks that even slower rates of decompression should be tried for pressures above 28 lb. +, below which this rate of 2 lb. per min. appears to be safe.

If it were possible, in accordance with Dr. Haldane's suggestion, to arrange a large decompression chamber in which a pressure equal to one-half the actual tunnel pressure could be maintained, where the men could pass a long decompression period in comfort, and use the time for bathing and dressing and, perhaps, for eating, it would probably prove a valuable means of preventing illness, and, at the same time, permit of working with comparative safety under higher pressures than could now be attempted.

Medical supervision and examinations are important and are instrumental in preventing serious results from the effects of compressed air. Men with organic disease are certainly less able to withstand the effects of compressed air than normal individuals. New men are certainly more susceptible to the effects of compressed air than old workmen. When high pressures are being used, a preliminary test of about 1½ hours under tunnel pressure for all new men, followed by a second medical examination, and short shifts of from 1½ to 2 hours for the first working period, are effectual means of guarding against serious results among new workmen.

Compressed-air work in tunnels and caissons, where pressures above 30 lb. + are used, will always remain a dangerous occupation in spite of all reasonable precautions, for one can hardly hope to prevent all cases of illness. Those cases due to small quantities of free gas are almost sure to happen, and a small proportion of them is likely to result in paralysis, which may cause permanent disability or death. Until the reason why certain men are susceptible to the effects of compressed air, can be learned, and such individuals can be recognized, cases of sudden death from large accumulations of free gas are almost certain to occur occasionally.

Dr. Albert J. Loomis.—After a pretty wide experience, extending back over twenty years or more, with pressures ranging from 15 to 42 lb., gauge pressure, the speaker cannot agree with the author of the paper, or his authorities, as to the cause of the disease under discussion. While admitting the "saturation theory" as laid down by Bert, von Schrötter, Haldane, and others, the speaker does not think that it is the cause of the so-called caisson disease, for the following reasons:

First.—As to the formation of bubbles of gas or air in the blood-vessels themselves: They have only been demonstrated in exceedingly high pressures—15 or 20 atmospheres—which, at the present times, are considered impracticable as working pressures. If these bubbles should occur in the blood-vessels of the men, working as they do and coming out as they do, there would never be any use for hospital locks, as the men would all die of suffocation before they could be gotten to them, owing to these minute bubbles becoming entrapped in the very small vessels or capillaries of the lungs, and thereby preventing the oxygenation of the blood, a condition which operating surgeons frequently meet, to their great regret.

Second.—If the symptoms were due to any change in the blood itself, there would be a general set attacking all parts of the body to a greater or lesser extent, which is the very thing that does not happen, but, on the contrary, they show themselves in a very few localities, and most of these localities are in the lower extremities, situations which any surgeon who is at all proficient in locating nervous lesions by their symptoms, would place without hesitation in the spinal cord, and in the lower portion of the cord.

On the other hand, there is practically but one set of symptoms, the so-called "staggers," which would lead physicians to look for a cause or lesion in the brain, a condition which is quite rare when compared with the great number of cases occurring in the lower extremities.

Should there be any change in the composition or condition of the blood, the brain would naturally be the first organ to show such change, as it is without doubt the most delicate organ of the whole anatomy.

In reference to the CO_2, the engineers of the North River Division of the Pennsylvania Tunnels have prepared a chart on which all the cases of compressed-air sickness have been plotted, and this chart shows that, on that work, the greatest number of cases occurred at a time when the CO_2 was only 1 part in 1,000, with a pressure of from 20 to 25 lb.; and, likewise, when the pressure was 28 lb.

and the CO_2 was 2 parts in 1,000, there were no cases of caisson disease.

While the speaker is not prepared to place much stress on the CO_2, other than as an indication of the general ventilation, he does think that weather changes play a very great part in the causation of the disease, as do also the habits of living of those engaged in the work.

When it comes to the examination of men, the medical officer should fit himself for the work by a close study of the conditions under which the men are to work, and his power of rejection should be absolute. The selection of the men should be the duty of one man who should be responsible for their welfare while they are at work under pressure.

In substantiation of these opinions, the speaker desires to state, that in the work of the Hudson Companies, in the construction of the Hudson and Manhattan Tunnels, about 38,000 men have been examined, since 1902, for pressures of from 15 to 42 lb., with three deaths, and in the construction of the North River tubes of the Pennsylvania Tunnels about 7,000 men have been examined for pressures of 15 to 38 lb., with no deaths.

WILLIAM L. SAUNDERS, M. AM. SOC. C. E.—This is a subject about which very little of practical value has been written, and the speaker is glad to note that Mr. Japp has gone into the matter in so much detail, both from theoretical and practical standpoints.

Caisson disease, or the "bends" as it is commonly called, does not differ from other diseases, in that doctors are very apt to disagree about it. Heretofore the subject has been treated in print mainly from a medical standpoint, various theories being advanced as to the cause of this disease, that is, whether it is due to mechanical or chemical action. The speaker remembers when the most plausible theory advanced for the cause of caisson disease was that the blood, which had been compressed and held in a state of tension, was suddenly released by decompression, creating a pain when coursing through the veins. This was illustrated by the statement that if a string is wrapped tightly around one finger and then suddenly unwound, the finger is temporarily in pain. The subject has been discussed so fully by Mr. Japp, however, and the theory of caisson disease has been so well established by the experiments to which he refers that it is now generally accepted that bubbles are the cause of the "bends."

Compressed air is the speaker's hobby, and in his early experience in seeking information about it he has soared, like the eagle mentioned by Mr. Japp, to a height of 3½ miles, where he has felt the earmarks of the "bends," and has descended to great depths in mines and in a diving apparatus under the sea, where similar sensations have been felt.

Personal experience in a matter of this kind always fits one to judge better the causes as well as the effects, and it may add something to the interest in this matter to recite an experience which the speaker had some fourteen years ago in the old Hudson tunnel, now called the McAdoo tunnel. This tunnel was started by Mr. D. C. Haskin a little before, or about the time of, the Centennial Exposition in Philadelphia, in 1876. Mr. Haskin conceived the idea of driving a tunnel under the Hudson River by maintaining a chamber of compressed air to hold up the face. He used no shield, and as the material through which he worked was more or less unstable, he met with considerable difficulty and some lives were lost. He sank his entire fortune in the enterprise, the work being taken up later by English capitalists, who contracted with Messrs. Pearson and Son to finish the tunnel. At that time E. W. Moir, M. Am. Soc. C. E., was in charge of the work, and the experience which he gained there has no doubt helped him to design and carry through the recent tunnel construction under the East River, which Mr. Japp has so ably referred to and with which he has been connected in so important a position. During the administration of the Pearsons, the late R. P. Rothwell, M. Am. Soc. C. E., at that time editor of the *Engineering and Mining Journal* and the speaker, were invited to examine the tunnel for the purpose of making a report thereon. About an hour was spent under some 35 lb. absolute pressure. Coming out of the locks rather rapidly, on reaching the washroom, the speaker was taken with a severe attack of the "bends," the effect being like that of a paralysis of the lungs. A horizontal tank, resembling a common horizontal boiler, was at hand, and the patient was transferred to a bench of straw, the door was closed, compressed air was turned on, and the relief was instantaneous. A pressure valve, provided for the purpose of admitting and

discharging pressure from the tank, was used to enable the air to escape, but it was noticed that when the pressure fell only two or three pounds the "bends" returned, and it was only by the gradual reduction of the pressure, occupying about ½ hour, that the patient was able to open the door and walk out cured. The necessity for reducing the pressure gradually, as shown very decidedly by the return of the "bends," indicates the value of the theory of gradual decompression. It also bears out the idea that time must be given to permit the escape of the little bubbles which accumulate in the body.

An interesting incident was noted in connection with this experience. When the pressure in the tank was lowered, through the discharge of air, a fog formed instantaneously, and as soon as air was let in and the pressure increased, this fog was as promptly dissipated. The speaker experimented with this for some time—manufacturing and annihilating fog. The lowering of pressure, of course, resulted in cooling the air, and, *vice versa,* increasing the pressure heated the air. As the air was cooled, fog was produced immediately when the temperature reached the dew point, the capacity of air for moisture depending entirely on volume and temperature, that is, a certain fixed volume of compressed air, or free air, can hold only a certain quantity of moisture at a certain temperature. If the temperature is raised, it will hold more water; if the temperature is lowered, the moisture must be precipitated, first in fog, and later in the form of rain.

Walton I. Aims, M. Am. Soc. C. E.—The literature on caisson disease is quite extensive. The causes of the disease now seem to be well determined, but difficulty is found in conforming practically with the medical rules and regulations for its prevention.

The age of the compressed-air worker has an important bearing on his ability to withstand the effects of too rapid decompression, but youth generally lacks experience, and, in difficult work, some compromise has to be made in drawing the age limit for entering the compression chamber. Dissipation acts strongly in undermining a man's resistance to the effects of compressed air, especially among workers of mature years, and even some temporary indisposition may occasion an attack in one who has previously been pronounced physically fit by a medical examiner.

In nearly all compressed-air work there is difficulty in compelling the workmen to take a reasonable time in the air-lock while decompressing. Believing that this is due largely to the extremely uncomfortable conditions in the ordinary air-lock, a method for relieving the lock of the cold and fog when decompressing was used at the Battery-Brooklyn tunnel by introducing a constant flow of heated dry air while the lock was being exhausted. In addition to removing the cold and fog from the lock, this heated air also provided for ventilation while decompressing, a feature not found in the ordinary compressed-air lock. The comparative freedom from caisson disease at the Battery-Brooklyn tunnel, where practically no age limit was established, seemed to indicate the value of thus heating and ventilating the air-lock during the decompression period.

Dr. Seward Erdman.—The speaker wishes to acknowledge his appreciation of Mr. Japp's instructive contribution to the literature of caisson disease, and feels that the general adoption of the suggested "Step Decompression Method" will aid much in robbing compressed-air work of its gravest dangers.

The reduction, to terms and curves of mathematical precision, of the time and pressure elements, as shown on his charts, is most interesting; but it seems to the speaker that there will always be another factor to be reckoned with, one which cannot be reduced to mathematical terms, and yet which will continue to render uncertain the result of exposure to compressed air in each individual case. This indeterminate factor may be called the "personal equation," and seems to be dependent on the functional efficiency of the circulatory and respiratory apparatus.

In the experience of all who have seen much of compressed-air work, cases are not infrequent where men who are seasoned air workers will work daily, for long periods of time, at fixed conditions of pressure, length of shift, and decompression time, without suffering any ill effects, but who will come to work the next day, under exactly the same conditions, only to develop a severe or even a fatal attack of "bends."

The decompression time, indicated on Mr. Japp's charts, can be controlled by valves from the air locks; but, for the individual, desaturation of the body tissues and the blood must take place through the lungs; therefore the lungs act as the "escape valve" for the indi-

vidual. In explanation of such accidents as are above cited, it is likely that this "escape valve" is temporarily clogged. Desaturation of any given part of the body will be impeded by causes which slow the blood current in that area. Thus passive congestion of the lungs, or the presence of mucus in the air spaces (as from a cold) may act as clogs to the "escape valve," thus increasing the time necessary for desaturation; and, under such conditions, the body does not rid itself of the gases in the average time, and an attack of "bends" results.

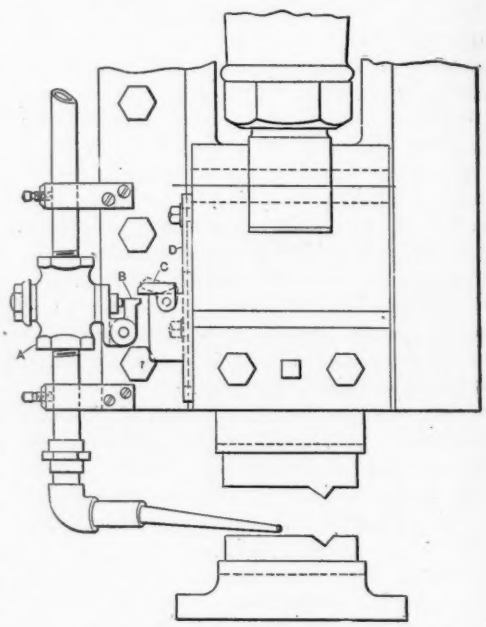
THE MECHANICAL ENGINEER'S SAFETY VALVE

The mechanical engineer is not very well recognized as a professional man in America, but he is coming to his own by and by. I got myself into a peck of trouble with my civil engineering friends by speaking out in meeting. I, of course, knew that the gentle art of killing people was several years ago the most prominent business of the day, and that military operations needed a military engineer, but when they got to doing peaceable things the man who operated things was called a civil engineer in counter distinction to his military brother, and civil engineers got into the business of building dams, waterworks, railroads, bridges and canals; but my own personal experience, I said, seemed to show that civil engineers figured up something, giving a lot of cubic feet of material, and figured up how much something was going to cost, then they hired a good Irish contractor who undertook the work and carried it along, and it was carried along by the work turned out in the shape of steam shovels, rock drills, boilers and engines, which were entirely the product of mechanical engineers, and when they got through the civil engineer's figures were anywhere from 100 to 600 per cent. from being correct. Of course, a civil engineer cannot see into the ground, and the weather cannot always be counted on, but it seemed to me that instead of being the "dog" a civil engineer was the tail of the profession of engineering.

I know some first-class civil engineers who do not figure as above, but they have either been practical contractors or practical mechanical engineers before they took up civil work. —*W. D. Forbes in American Machinist.*

A DIVER CLEARS THE PUMP

The Draper mine, at Soulslyville, Cal., has been idle for five years and it was lately decided to unwater it and resume operations. Two 10 in. pumps were in the shaft, but while the mine had been idle a cave-in had occurred, so that it was impossible to start them. Air was used to raise the water above the 350 ft. station, and when the pump there was reached it was put into operation. The air was then applied to raise the water still below this pump to reach the other at the 600 ft. station, but when the water was down to within 75 ft. of this the air lift failed to work. A diver was then employed who found the suction of the pump almost entirely covered with mud and loose rock. After a day's work he had so cleared things away that the water was then lowered rapidly and the bottom of the shaft was soon dry again.



COMPRESSED AIR BLOWS THE WORK AWAY

The cut shows an arrangement for blowing work from a forming die in a punch press, as used upon about forty presses in a large plant. A plain forming die is shown in position under the plunger and at the left of the plunger is the valve A with its attachments. This is a Lunkenheimer whistle valve held by the pipes at-

tached to each end, which in turn are held by the clamps attached to the frame. Below the valve there is a union and other connections with a bent tube which may be turned as required to give the best effect. The regular whistle valve tube has been removed and in its place the trigger B is mounted. This trigger remains in the position shown when not in action. On the descent of the plunger the pawl C swings back to pass the trigger but on the upstroke it pushes the trigger and causes a puff of air which removes the formed piece on the die. Other uses of the device will suggest themselves.—*Machinery.*

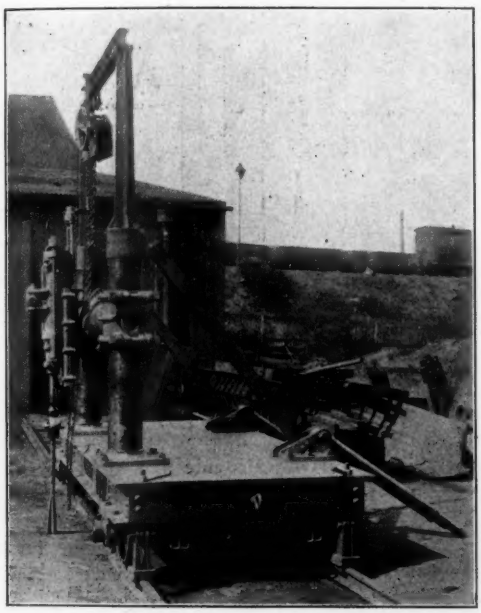


FIG. 1. VERTICAL DRILLING.

A SPECIAL TRUCK FOR HEAVY DRILLING

The little half tones herewith tell very satisfactorily the story of a special drill truck built by the Ingersoll Rand Company for a foreign customer. The truck provides not only for the carrying of heavy drills, 3½ to 5 inch, but embodies in itself the securest and firmest possible mounting for the drill at work, with facility of handling and a very complete range of adjustment. The chain hoist locates the crossbar so that it can be clamped at any height, and the drill saddle may be slid anywhere along the bar and set at any angle in the vertical plane or laterally as required. The legs at

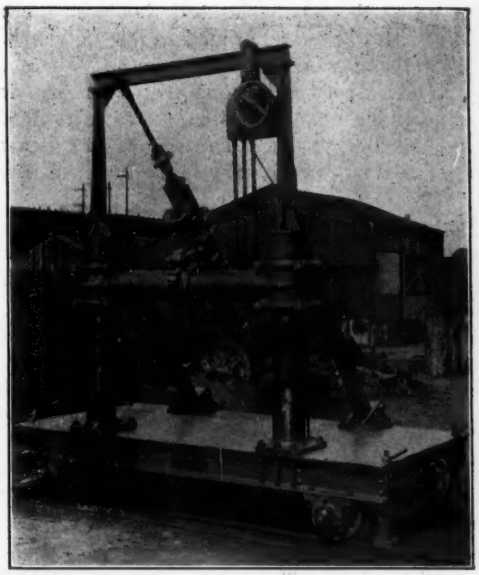


FIG. 2. ANGULAR DRILLING.

the back are tightened by the jackscrews to steady the frame when the drill is at work and the car is firmly clamped to the track at each corner, the clamp being tightened by driving down the clamping collar. Fig. 3 shows how

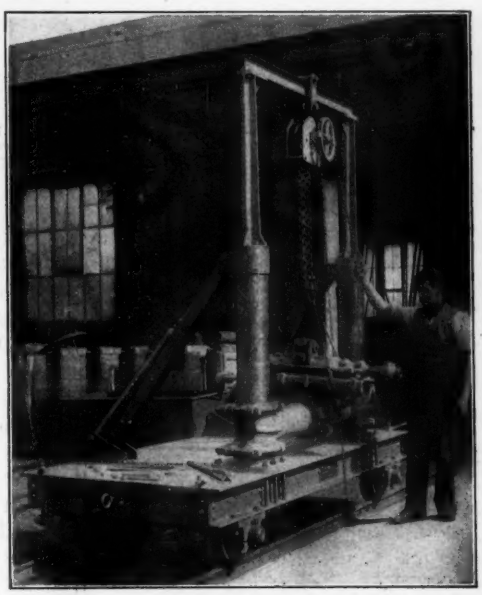


FIG. 3. READY TO MOVE.

the track clamps and the back legs swing up out of the way. The drill shown on the bar can also be swung around so that nothing will overhang when the car is moved along the track. It is understood that with this drill mounting holes are to be put down to depths exceeding 50 feet. The solidity and general adaptability of the rig speak for themselves.

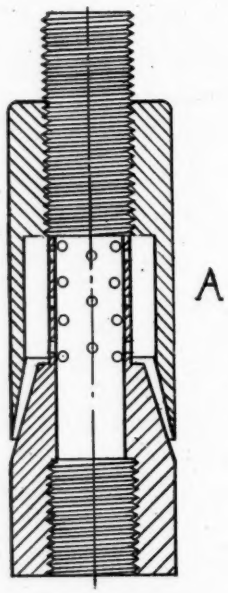
AIR LIFT PRACTICE

The following is from a "talk" by Mr. Sam Skelly before San Francisco No. 1, N. A. S. E., as reported by the *Journal of Electricity, Power and Gas.*

The utility of the air lift for handling water is most evident where a number of wells are to be operated at some distance from each other, or from a central plant, and where large quantities of water are to be brought to the surface or water impregnated with mud or sand is to be pumped; these conditions making steam or power driven pumping machinery expensive to instal, uneconomical in operation and costly as to maintenance. In such conditions the air compressor can be cheaply substituted for numerous pumping heads, and the air piped to the various wells at small expense. The air lift, if properly installed, will work satisfactorily with practically no attention, requires no repairs and will handle dirty water that would ruin a pump, without trouble or damage to itself.

The principle of operation of the air lift was simply explained as being the creation of an effective head between two columns of water by lessening the density of the discharge column with the introduction of air intimately mixed in the ascending column. In order that this head shall be practically effective there must be a degree of submergence proportional to the proposed lift. This was stated to be about 60 per cent. for a reasonable efficiency. Under such conditions as high as 75 per cent. efficiency has been attained. When the quantity of water raised is greater than the supply, causing a reduction of level and less submergence, the efficiency decreases rapidly, approximately as the cube of the distance of drop of water level. Greater submergence than 60 per cent., however, gives no additional advantage, and where the depth of water exceeds this the apparatus should be submerged only the necessary depth.

The sketch shows an air improved jet designed by Mr. Skelly, wherein the air is introduced with the lift pipe in a film which gives a constant flow of water. The thickness of the film can be varied by screwing the sleeve A up or down.



An empirical rule for determining the size of discharge pipe to use for ordinary purposes is as follows: Provide one square inch area of discharge pipe for each four cubic feet of free air per minute capacity of compressor. This rule gives excellent results for the usual conditions found. An air pressure of four atmospheres is found to give best results under the same conditions. (The pressure must, of course, vary according to the submergence. Ed. C. A. M.) The substitution of several small pipes of equal aggregate area instead of one large pipe for the discharge gives better efficiency on account of the fact that the tendency of the air to create a hollow column inside the large pipe is thus overcome. This arrangement is also easier to install on account of the smaller pipe used.

In cases where the discharge is to be in elevated tanks at some distance from the well, it is necessary to carry the discharge directly to the necessary height and then terminate with a horizontal run, or where this is not feasible a stand pipe may be provided to re-

ceive the water from the well and otherwise piped to the storage tank.

The apparatus will not work satisfactorily with a horizontal run in the discharge below the level to be reached on account of the fact that the air being lighter than the water will separate from the column and leave it dense at the bottom of the pipe.

Under certain conditions a dual system may be installed, using the air lift to bring the water near the surface, and from that point taking it with a suction and lift pump to the tank. The cup at the bottom of the pump suction collects the water from the air lift column, the air passing on upward, providing a continuous supply to pump. This system is applicable to deep wells where the conditions will not permit the use of the air lift alone and where a deep well pump is not advisable.

There are many cases where the use of an air lift instead of a pump is attended with incidental advantages, as when the water is to be used for cooling or condensing purposes, the refrigerant effect of the expanding air being sufficient to lower the temperature of the entire body of water, in some cases as much as twenty degrees.

BUSINESS OPENINGS FOR ENGINEERS

A recent leader in *Engineering-Contracting* speaks of the business opportunities inviting the engineer in the production of crushed stone for concrete contracting and goes into details as to the possibilities of reducing costs. A few of the suggestions follow:

We do not know of a single quarry where the drillers are paid on "the hole contract system," that is, on the basis of a piece rate per lineal foot of hole drilled. It has been demonstrated again and again that by paying rock drillers according to the number of feet of hole drilled—whether by a straight piece rate, or by a differential piece rate, or by a bonus system—the output is increased 50 to 100 per cent. This needs no argument, but, unfortunately for both drillers and quarry owners, there exists such a mental inertia among business men that changes in methods of payment and management are about as slow in developing as are changes in the styles of building bird's nests. This very adherence to old methods, however, constitutes the secret of the real opportunity that lies before the engineer who goes into business, for he enters it free from the tyranny of precedent and with a mind keenly critical of the old methods and eager to try the new.

In all the quarries that the writer has visited he has not once seen a water jet in use for the purpose of removing the sludge as rapidly as formed and thus accelerating the speed of drilling. Here, again, is a method about which there can be no dispute, for it has been tried in all kinds of rock and rarely without an astonishing increase in the number of lineal feet of hole drilled by each machine. As far back as the great Hell Gate blast in New York harbor, the water jet was found to cause an increase of 25 per cent. in the drill output when working in the gneiss and mica schist that was encountered. Yet there are hundreds of self-called "experts" in excavation who believe that a water jet is of no use except in soft shales and the like. There are water jets and water jets. If the current of water that flows from a drill hole is weak, it will raise only the most minute fragments of sludge; but if it is a trifle stronger, rock chips of considerable size are elevated and removed, thus freeing the drill bit of the work of pulverizing the chips.

In all the quarries that we have visited we have not seen one drill sharpening machine in use, although such machines are commonly found as a part of the plant used in mining. This, in itself, is not a matter of great economic moment, perhaps, but it merely shows the general ignorance or apathy existing among most of the men who run quarries.

Chamber blasting is almost unheard of among quarrymen, although it is the most economic known method of loosening large quantities of rock, both as regards the cost of drilling and of explosives. It is true that, after making a chamber blast, the largest chunks must be drilled and blasted. However, when a chunk of rock is free on all four sides, it requires comparatively little powder and a correspondingly small amount of drilling to break it up. In the breaking up of these chunks, both the ordinary rock drill and the pneumatic plug drill (or hammer drill) are used to advantage, the former for the biggest chunks and the latter for the smaller pieces.

Perhaps the commonest economic blunder seen in quarry work is the use of rock crushers of small size. A small crusher necessitates either the close spacing of drill holes, or the

sledging of pieces of blasted rock, or both. The average quarry owner seems to reason that because his daily output will not be large he does not need a crusher of a size larger than will just deliver this small output. The fallacy in this sort of reasoning is seldom discovered, for the close spacing of drill holes, and even the sledging of the rock, come to be regarded as necessary.

In so simple a process as the feeding of a rock crusher there is a woful lack of know how. Feeding from bins or chutes enables one man to do more work than three or four men can do when lifting stone from a floor into a crusher.

To the engineer who contemplates going into the business of producing crushed stone, we would suggest the advisability of first studying the literature on rock excavation—including all catalogs—with care. This should be followed by a trip through the country, visiting not only the ordinary crushing plants that are run by manufacturers of crushed stone for concrete, ballast and macadam, but also the large plants operated at Portland cement factories, and particularly the milling plants at some of the metal mines. Often a method in use on a large scale can be modified and adapted for use on a small scale, so that the mere fact that a plant is very large and elaborate should not militate against a study of it by a man who contemplates installing a small and simple plant.

SURGERY AND PURE AIR

What may come to be known in the history of surgery as the Bush Case is likely to have considerable weight among sufferers from appendicitis, according to the memoranda of Drs. McBurney and McArthur, the surgeons in charge of the operation upon C. Adolph Bush, a boy upon whom the operation for appendicitis was performed aboard the Mauretania on a recent trip eastward. The ship was three days out from New York when the boy's condition became serious, and the expert surgeons, who very fortunately were on board, decided to operate at once. The captain offered to shut down the engines during the operation, but this was declared unnecessary by the doctors, since the sea was smooth and the weather clear. So the operation was performed while the ship was making twenty-three knots an hour.

The point—one might say the McBurney point—of great interest both to the patient and the whole profession is that the boy recovered consciousness much more quickly than usually occurs in hospital cases ashore, and immediately began to mend. His progress was rapid and by the time the ship docked at Liverpool the physicians agreed that he might safely be removed to the Liverpool hospital, where he was considered out of danger and expects to continue his journey to Scotland in a very few days. The telegram from London describing the occurrence informs us that Drs. McBurney and McArthur attribute the quick recovery not only to the physical buoyancy of the young patient, but in a great degree to the exhilarating effect of the sea air and the absence, at sea, of deleterious germs.

This being the case, marine operations for appendicitis will naturally become almost imperative, for it is the merest common sense to give the patient every chance. The number of sufferers from appendicitis who are not financially able to command their own steam yachts for the operation, or at least to go to sea on a big steamship, is so small as to be neglible. Therefore it will soon become bad surgical form to perform this operation ashore, and in a short time an operating room will be a more necessary part of a ship's equipment than, say, a "Social Hall," or a theatre.

The upholders of mountain climbing as a sport may contend that the air at the summit of almost any peak is as wholly free from germs as the air in midocean; but the seagoing surgeons will doubtless retort that the patient's heart would be more likely to give out under chloroform at a height of from three to five miles above the sea level than on the sea. So the marine operation is likely to be preferred *Evening Sun,* N. Y.

[It can hardly be presumed that mountain air is as pure as that in mid-ocean; besides that and the levity of the air, there would be complications as to temperature, not to speak of the difficulty of safe and comfortable transportation.]

At a meeting of representative electrical engineers of South Africa, held at the Grand National Hotel, Johannesburg, South Africa, on July 12 last, a new electrical institution was founded with the name and title of the South African Institute of Electrical Engineers.

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EVERYTHING PNEUMATIC

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THE INTAKE PRESSURE IN AIR COMPRESSOR CYLINDERS

We have before us a copy of a paper by Mr. A. C. Whittome, read before the Transvaal Institute of Mechanical Engineers and printed in the Journal of the Institute. The paper deals with the general problem of "Compressed Air Production and Use," and has the special merit of calling attention to more of the factors of the problem than are usually recognized, and of stating the entire case with unusual candor and clearness.

We mention the paper here, however, rather to take exception to one of its assumptions as not warranted and as not sustained by the explanation which the writer offers. Speaking of the typical air cylinder indicator card the paper says:

"It is hardly necessary to state that the inlet lines must be below the atmospheric line (for low pressure cylinders, or intercooler line for high pressure), even if mechanically opened inlet valves are employed, the friction in pipes, passages and ports, and the changes of velocity, etc., ensuring some slight drop. If spring loaded inlet valves are employed this drop below atmospheric pressure will be increased, and the proportion of work performed in drawing air into the cylinder will rise also. And yet how seldom it is that a card is seen on which the pressure at the end of the inlet stroke does not practically coincide with the atmospheric line; in fact, it is nothing unusual to see it shown on the top edge of the atmospheric line. It is frequently claimed that this is due to the admirable system of inlet valves employed on the compressor, and their excellent condition, the fact being ignored that if it needs an excess of pressure on the outside of the cylinder to overcome pipe friction and the resistance of valves, this excess of pressure must also be, to some degree, apparent at the end of the stroke, otherwise air will not flow into the cylinder. The real reason that the pressure rises to atmospheric (and sometimes above it) at the end of the inlet stroke, is that the air has become heated by passing over hot surfaces and by contact with cylinder walls and head and piston, and the pressure has thereby been increased."

We are compelled to characterize the explanation as absurd. It is undoubtedly true that there is no compressor built, and apparently no possibility of designing one, in which

the air at normal atmospheric temperature must not pass over or come in contact with some metallic surfaces at a temperature higher than this before it is actually within the compressing cylinder and ready for the compression to begin, so that we may say that, by conduction or radiation, the temperature of the cylinderful of air at the instant when compression begins must always be somewhat above that of the outside air. Whatever may be this use of temperature, however, it can in no way affect its pressure until the inlet valve is closed. During the suction or intake stroke the only thing which causes the air to flow into the cylinder is the pressure of the atmosphere behind it, or the excess of this pressure above that within the cylinder at the time. Whatever heating of the air occurs while it is rushing into the cylinder can only slightly augment its volume and not at all its pressure, and the increase of volume only cannot account for the height of the intake line at the moment when intake ceases and compression begins.

There seems to be an unaccountable hesitation about accepting what is apparently a very satisfactory and complete explanation of the phenomenon. Air has weight and inertia, and if we have it in a column which is alternately moved forward at a considerable velocity and then brought to rest, the alternations occurring quite rapidly, there must of course be an increase of the difference between the pressure in advance of the column and the pressure behind it which will cause the inrush of the air, and then to suddenly stop the advance of the column this pressure difference must be reversed. As the pressure behind the column is constant, being that of the atmosphere, the required reversal of the pressure difference can only be produced by an increase of pressure in front of the column, which is just what the indicator card shows in the cases under consideration.

A little look at actual, practical conditions will enable us better to realize what occurs to the intake air when the compressor is in full operation. We have to assume the existence of the column or elongated mass of air first of all, the sectional area of it being such that a high velocity of flow occurs. Where the inlet valves are in the cylinder head and not encased, so that the air is drawn in from that immediately surrounding the cylinder the inertia of the air of course counts for nothing for increasing the final intake pressure, but when the intake air is piped to the compressor in a pipe of suitable size to bring the air from outdoors, or from where it is coolest and cleanest, then we have the conditions looked for. With the piston inlet the column of intake air is a necessary condition, and compressors of this type quite generally show the cylinder full, or, as we might say, a little more than full of air at atmospheric pressure at the beginning of the compression stroke. The same phenomenon would be shown by other compressors giving the same conditions —a pipe of dimensions just adapted to the volume flowing through it, a full opening into the cylinder and a quick closing of the valve at the precise moment before compression begins.

ACCURATE SURVEY WORK

The meeting of the headings of the Gunnison tunnel affords an opportunity of checking up the survey work for laying out the tunnel. The tunnel is six miles long and survey had to be conducted through a very rough country in order to locate the two ends. Naturally, the survey lines were very much longer than the tunnel; hence, an exceedingly small error in the survey would have resulted in very serious error when the headings met. An error of one minute of an arc in a line six miles long would throw the alignment in error by at least nine feet. Yet, when the headings of the Gunnison tunnel came together it was found that the error in alignment was less than one-half an inch, in grade less than four inches and in length about ten inches. The figures given out by the Reclamation Service are as follows:

Error in alignment	0.04 ft.
Error in level	0.32 ft.
Error in length	0.86 ft.

It may be of interest to compare this work with that done in laying out some other famous tunnels. In 1875 the Musconetcong tunnel on the Lehigh Valley road was found to be in error when the headings came together as follows:

Error in alignment	0.04 ft.
Error in level	0.015 ft.
Error in length	0.52 ft.

The length of this tunnel is about one mile, and shows exceedingly good work for commercial purposes.

The Simplon tunnel in Switzerland is be-

yond question the greatest tunnel project ever completed, and the survey problems presented were such as to tax the surveyors' skill absolutely to the limit. The portals of the tunnel are 19 kilometers apart, or about 13 miles Each entrance of the tunnel is made on a curve and there were several changes of grade in the tunnel. Combined with this, the triangulation lines had to be carried over some of the roughest country in the world. Yet, in spite of all these difficulties, when the tunnel was completed the survey errors were found to be as follows:

Errors in alignment..... 0.202 meter
Errors in level ..... 0.087 meter
Errors in length ..... 0.79 meter

While these errors appear to be much greater than in the other two cases cited, yet, when one considers the tremendous difficulties in surveying in the Swiss Alps, the work of surveying for the Simplon tunnel must set a standard of accuracy to compare all other similar work with.

Some remarkable surveying work has been done also in mining. A number of years ago it was desired to rapidly sink a shaft in the Freiburg district in Germany. The shaft was worked from about a half a dozen different levels by means of raises and winzes. In order to fix the points for the miners to start work from, several miles of survey lines had to be run. Yet, when the shaft was completed, the error was so minute as not to be detected by most careful measurement.

Of course, it is not proper to compare commercial survey work with the goedetic work done under government auspices, yet an example of how accurately triangulation work can be done is given by the reciprocal measurement of the two main base lines from which the survey for the British Islands was started. These two base lines, which are several miles in length, are situated one in the north of Ireland and the other in the south of England. The Lough Foyle base line in the north of Ireland can be seen across the ocean from the south of Scotland. Taking the Lough Foyle base, a series of triangles were carried to the ends of the Salisbury Plain, or the south of England base line. On comparing the calculated length of the Salisbury Plain base line from the length of the Lough Foyle base with the actually measured length of the former base there was a difference of five inches. The Salisbury Plain base line is about five miles long, and thus there was an error, or rather a difference by triangulation and measurement of about one inch to the mile.

Now comparing the commercial work of laying out the Gunnison tunnel with frequently admired British Survey Service, it will be found that the error in length of the Gunnison tunnel, as shown by the difference between the triangulation and the measured length of the Gunnison tunnel, is about one and two-thirds inches to the miles, as against one inch to the mile as recorded in the previous paragraph.—*Mining Science.*

A TUNNEL USED FOR COMPRESSED AIR STORAGE

The following interesting account of the successful use of a discarded tunnel for the purpose of storing a considerable volume of compressed air is contributed to a recent issue of *Power and the Engineer* by Mr. C. Sangster, Rossland, B. C.

In any compressed-air plant a large receiver capacity that can store the air when the consumption is light and restore it when consumption is correspondingly heavy is very desirable. This is especially true of those plants where the compressor is driven by an electric motor. The conditions are then a compressor having constant speed and, in mining work, a constantly changing load.

Compressors of modern design for electric drive are equipped with unloading devices which overcome, to a certain extent, the loss of power through the blowing off at the safety valve when a hoist or a number of drills are stopped for a few minutes. But with an unloader thus cutting out the compressor every few minutes the daily capacity of the plant is very much less than if it were allowed to compress air constantly, and if that air could be stored and given back when all the drills and hoists happened to be at work at the same moment, calling for more air than the compressor could deliver, a great advantage would be gained.

The storage capacity of the ordinary mining installation is very small. Suppose a ten-drill plant has a storage equal to 5000 feet of 6-inch pipe and a receiver 48 inches by 15 feet. These combined would hold 1188 cubic feet of compressed air, which at eight atmospheres would be equal to 9504 cubic feet of free air.

If the compressor were stopped, only about one-third of this air could be used, as when about that amount had been drawn off the pressure would be too low to do effective work. Ten 3 1-4 inch drills at a 3000-foot altitude would pull down the pressure in this pipe line and receiving tank from 96 to 60 pounds in about four minutes.

At one of the mines in this district they have two electrically driven compressors with a combined capacity of 7500 cubic feet of free air per minute. These machines are equipped with automatic unloading devices which operate whenever the air rises to 100 pounds per square inch.

The idea of sealing up an unused crosscut in the mine and making of it a large underground air receiver was successfully carried out. The crosscut was roughly 9 feet high, 6 feet wide and 400 feet long and was driven through solid rock which showed no cracks nor seams. The bulkhead was built of concrete, 10 feet thick and carefully pointed on the inner side with strong cement. A 6-inch pipe connection and a manhole were built into the bulkhead; the manhole being sealed the same as a manhole in a boiler. When tested, it was found that this natural receiver lost only 10 pounds in 18 hours, one or two very small leaks around the bulkhead no doubt accounting for this loss.

The capacity of this crosscut is not less than 22,000 cubic feet, or is equal to 117 ordinary air receivers 48 inches by 15 feet. In free air compressed to eight atmospheres, it will hold 176,000 cubic feet, or the entire output of the compressors for 23 minutes. Allowing that one-third of this air is available at a working pressure, as cited, ten drills could be operated for 50 or 60 minutes after the compressor was stopped.

The advantage of such a large storage is very noticeable in the engine room. It tends to balance the rapid fluctuations in the load, the compressor and rope drive run more steadily and the unloaders cut out less often. The motors are not subjected to the strains of the load being constantly thrown off and on.

In the mine, a hoisting engine or a group of drills may be thrown on or off without seriously affecting the air pressure. In short, it stores and restores the air, piling up a reserve when a machine is stopped and giving it back when a sudden call is made.

This idea is not new, but the writer does not know of any other place where it has been successful, the difficulty usually encountered being the leakage of air through seams in the rock.

ATMOSPHERIC HUMIDITY THE SAFETY FACTOR IN COAL MINES

The following is from a paper by Peter Hanraty, Chief Mine Inspector of Oklahoma, before the Mine Inspectors Institute of the United States, Scranton June, 1909.

In studying and discussing the atmospheric conditions in the mines with shot firers and other parties, I maintained that if we could create the same temperature and moisture in winter as we had in summer, explosions would be almost unknown. In the winter of 1886, it was almost impossible to get shot firers. Many nights I had to fire the shots alone. It was on one of those nights that the idea struck me to use the exhaust of the pump, and the more I studied and experimented, the more convinced I became that steam was the solution of the problem. We not only used the exhaust from the pumps, but we laid pipe and allowed steam to escape into the intake airway. The steam as it escaped warmed the air, making the mine's condition practically the same in winter as in summer. We had no windy shots or explosions when we used the steam, but the moisture produced by the steam caused a slacking or disintegration of the roof, and, the slope and entries not being timbered, large falls were frequent, which entailed quite an expense, and orders were issued to discontinue the use of steam, which was done. In a very short time windy shots and disastrous explosions again commenced to become numerous. The following winter I quit the dangerous occupation of firing shots, and since that time numerous shot firers have been killed by explosions, and the number will continue to increase unless steam is used to heat the intake air, for explosions never happen from shots that have been fired after the air has traveled a long distance from the intake, and where the air has become the same temperature as the mine itself, but always happen nearest the intake, where the air is the purest and coldest. Nothing has occurred to change my views in the last 24 years; but continuous observation and investigation of explosions since that time has proven beyond the question of a doubt,

that to overcome the dangers due to a cold-air current entering a mine and having its capacity to absorb moisture raised by the natural heat of the mine, it is necessary to heat the intake air and saturate the same at a point near the foot of the shaft, so that the air will pass into the workings at a normal temperature and practically saturated. I feel sure that if the atmosphere of the mine is always in the same condition, not allowing any change in the atmospheric conditions, due to sudden changes of temperature on the outside, such as the difference between summer and winter, if the ventilation is not in any way stopped, and if we keep the absolute amount of water vapor in the air-current always the same, then coal dust will not and cannot explode.

The custom of slowing the fan or in any manner reducing the circulation at, or just previous to, the firing of the shots, should be prohibited. The idea that mines are getting too much air is simply an endeavor to justify those who have too little. I believe that 50 per cent. of the shot firers that are killed in this state from windy shots, die from the effects of afterdamp, due to the insufficiency of air caused by the slowing or shutting down of the fan. A large volume of air should be maintained at all times and the temperature of the mines kept the same.

NOTES

The production of mineral wool in the United States in 1908 was 9197 short tons, valued at $77,228.

A pumping engine which was installed in 1815 is still in service at the Dolcouth tin mine in Cornwall.

According to the census of 1905, 44 per cent. of all the water power used in the United States is employed in the production of pulp wood and print paper.

Hot, moist air is oppressive because being saturated with moisture, or nearly so, evaporation of perspiration, which cools the body, takes place only slowly.

A borehole 7,370 feet deep is being drilled near Rybnik, in South Western Germany. By December, 1908, it had reached a depth of 7,070 feet, with a diameter of 2 inches.

A business communication in Arabic which came to a Manchester firm, when translated by a Syrian interpreter, was made to ask the price of "two water sheep," when really two hydraulic rams were wanted.

Mr. Frank H. Hill, long identified with the sales and engineering department of the New York office of the Sprague Electric Company, assumed the duties of Manager of the Branch Office in Atlanta, Ga., on Sept. 1st, in place of Mr. F. V. L. Smith, resigned.

At Radley, Ind., a considerable length of 10 inch gas pipe belonging to the Indiana Natural Gas and Oil Company, and buried three or four feet in the ground, exploded recently under a test pressure of 70 pounds. The ground was torn up and the pipe was hurled up in the air, but no one was hurt.

When firing a broadside of eight 12-in. guns, the Dreadnought of the British Navy, which is a vessel of 18,500 tons, slid sidewise several yards and listed heavily. Each of these guns is 53 ft. long and fires a shell weighing 850 lb. at a muzzle velocity of 2000 miles an hour, using a charge of 265 lb. of cordite.

At a quarry in Connecticut recently the men were busily drilling the rock when the drill steel broke and a large piece struck a large glass bottle of gunpowder while another piece struck the rock, producing a spark which fired the powder, and three men were severely burned and cut.

Mr. Quistgaard, a Swedish engineer, has published a plan for connecting Copenhagen and Malo by an electric railway through a tunnel under the Oeresund. The present line between Copenhagen and Malo is 22.35 miles while by the proposed tunnel route the distance would be 9.9 miles.

A mercury telescope has been experimented with by Prof. R. W. Wood, of Baltimore. The reflector is a twenty inch basin of mercury which when rotated becomes a concave mirror of focus varying with the speed. It is now proposed to make one ten or twenty feet in diameter for some southern station where it can be used for photographing details of the stars as they pass directly overhead.

According to a report to the Finance Commission, the cost of bricklaying by the Sewer Department of Boston, using day labor, ranged from $9.04 to $18.34 per thousand. The number of bricks laid per hour per man varied from 13 to 242. On the small sewers, built under contract in connection with the Metropolitan work, the cost ranged from $2.77 to $4.23, and the number laid from 165 to 384. The high cost for the city work was attributed to lack of sufficient work to keep the masons busy.

An altitude of 38,714 feet is reported to have been reached by Lieut. Mina, of the Italian army and Mr. Mario Piacenzo, on Aug. 10, with the balloon "Albatross." The balloon was a spherical bag of 2,000 cubic meters (70,000 cubic feet) capacity, but only 1,200 cubic meters of gas was carried at the start. A supply of oxygen was carried for breathing. A temperature of —24 degrees F. was recorded. The previous record for altitude was 37,000 ft., and was made by Messrs. Coxwell and Glaisher in 1862 in England.

The Chicago public laboratories recently made tests to determine the amount of soot and dust deposited from the air in that city. The acreage deposit, as estimated from samples collected at eight different points of different heights during a period of four weeks was, approximately, at the rate of 8.5 tons per acre, per year. On the Board of Trade building, 110 ft. above the street level, the estimated annual deposit was 10.5 tons. On the county building, 160 ft. above street level, the amount was 7.8 tons, and on the Reaper block, 12 ft. above street level, 12.6 tons.

The loftiest chimney in the world was recently put into service at the large smelting works at Great Falls, Mont., where it will serve to carry off the gases from the greater part of the large plant. The chimney, which is built of brick, is 506 feet in height above the ground. It is 50 feet in diameter at the top, and increases gradually in diameter to the base. The flue includes a dust chamber in which vertically-hung wires serve to take out the dust from the smoke. The dust is removed from the wires by shaking mechanism and falls in hoppers in the floor, from which it is loaded into cars in a pit below.

Deep mining in Victoria makes systematic ventilation imperative, if only to secure a tolerable working temperature. In order to carry on economical mining it is necessary to have as large a volume of air circulating through the workings as possible. For instance, at 4,254 ft. the rock temperature, 113.5 degrees, and the water, at 114 degrees F., requires a volume of natural air of not less than 10,000 cu. ft. per min. to maintain a temperature of 72 to 75 degrees. The temperatures vary from summer to winter. In driving dead ends a system of overhead bratticing has been introduced to keep a current of air circulating to the face. A volume of 1,250 cu. ft. is required in one mine to maintain a temperature of 86 degrees. This system is the best yet developed for deep ground. Blowers have been tried, with poor results, the ground being so hot the pipes acted as conductors and made the air too hot in a distance of 400 ft. They have been found to heat the air 10 degrees.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

AUGUST 3.

929,655. THERMOSTATIC REGULATING DEVICE. WILLIS H. CARRIER and EDWARD W. COMFORT, Buffalo. N. Y.

929,740. EXPRESSION DEVICE FOR PNEUMATIC PIANO-PLAYING MECHANISMS. JOSEPH WIESER, St. Johnsville, N. Y.

929,746. CLEANING DEVICE. PATRICK A. BAYLESS and ARTHUR C. HEIN, Oklahoma, Okla.

929,764. MILKING-MACHINE. JOSEPH H. HOOVER, Waterloo, Iowa.

929,799. VACUUM-PUMP. JAMES L. SPARKS and EDWARD R. EDDINS, St. Louis, Mo.

929,832. SUBAQUEOUS ROCK-BREAKER. BARTON H. COFFEY, Boston. Mass.

929,909. AUTOMATIC CUT-OFF FOR PNEUMATIC-DESPATCH-TUBE SYSTEMS. FRANKLIN H. WOLEVER, Chicago, Ill.

930,025. VACUUM SEALING APPARATUS. GEORGE A. BEARDSLEY, East Orange, N. J., and DANIEL WARDELL. New York, N. Y.

930,087. ATOMIZER FOR PAINT OR THE LIKE. REINHOLD REICH, Berlin, Germany.

930,120. AUTOMATIC AIR-GOVERNOR. LEWTER W. BAKER, Wilmington, N. C.

930,122. APPARATUS FOR EXTINGUISHING FIRES. JOSEPH O. BANNIN, New York. N. Y.

930,125. PORTABLE VACUUM-CLEANER. CHARLES F. BARRETT, Bridgeport, Conn.

930,127. PNEUMATIC FEEDER. EDWIN M. BASSLER, Chicago, Ill.

930,225. CONTROLLING MECHANISM FOR LOCOMOTIVES. EUGENE L. RAGONNET. Bowdoinham, Me.

4. The combination of a cylinder, a piston, a valve chest connected to a source of fluid under pressure, and to said cylinder, a valve in said chest, means for operating the valve at will, means including a movable member for connecting the piston to the reversing gear of the

engine, a bar fulcrumed on said movable member and also connected to the valve, and means for operating said valve including an element also connected to said bar and capable of acting as a fulcrum therefor, and a device for limiting the range of movement of said bar in both directions.

930,268. APPARATUS FOR STORING, SUPPLYING AND UTILIZING MINERAL OILS, ETC. JOHN F. CONNELL, Los Angeles, Cal.

3. Apparatus for storing, supplying and utilizing mineral oils, consisting of a storage tank under atmospheric pressure, a service tank under pressure greater than that of the atmosphere, the connections between the storage and service tanks, means for opening and closing said connections, a compressed air reservoir, a separator, a pipe and means for opening and closing communication between the compressed air reservoir and the service tank, a burner, means for connecting the separator to the burner, means for connecting the service tank and separator, a boiler, means for connecting the steam space of the boiler with the burner, a pipe with an opening and closing device at its top connecting the storage tank with a street opening.

930,273. TIRE-INFLATION MECHANISM. FREDERICK A. DEUNERT, Kayabram, Victoria, Australia.

930,315. PNEUMATIC COUPLER FOR AUTOMATIC MUSICAL INSTRUMENTS. WILLIAM H. REES, Worcester, Mass.

AUGUST 10.

930,379. AIR-BRAKE APPARATUS. LEE L. HOSACK, Youngstown, ALBERT H. GELTZ, Alliance, and WALTER W. MCBANE. Youngstown, Ohio.

930,424. AIR HEATING AND CIRCULATING SYSTEM. CHARLES H. SMITH, Minneapolis, Minn.

930,430. PERCUSSIVE ROCK-DRILL. WILLIAM C. STEPHENS, Cornwall, England.

930,564. METHOD OF OPERATING MULTI-STAGE PRIME MOTORS. PETER G. SCHMIDT, Tumwater, Wash.

1. That method of utilizing a fluid under pressure in the operation of a multi-stage prime motor which consists in subtracting separate portions of such fluid pressure and conducting the same to the successive elements of the motor, each successive portion having a decremental pressure, and renewing the initial pressure supply at intervals determined by the cycle of operation of the motor.

930,567. GAS-COMPRESSOR. THOMAS SHIPLEY, York, Pa.

930,627. SPRAYING APPARATUS. HILLDRETH F. B. SNYDER, Hood River, Oreg.

930,628. AIR-SUCTION CLEANING APPARATUS. ARTHUR H. SQUIER. Philadelphia, Pa.

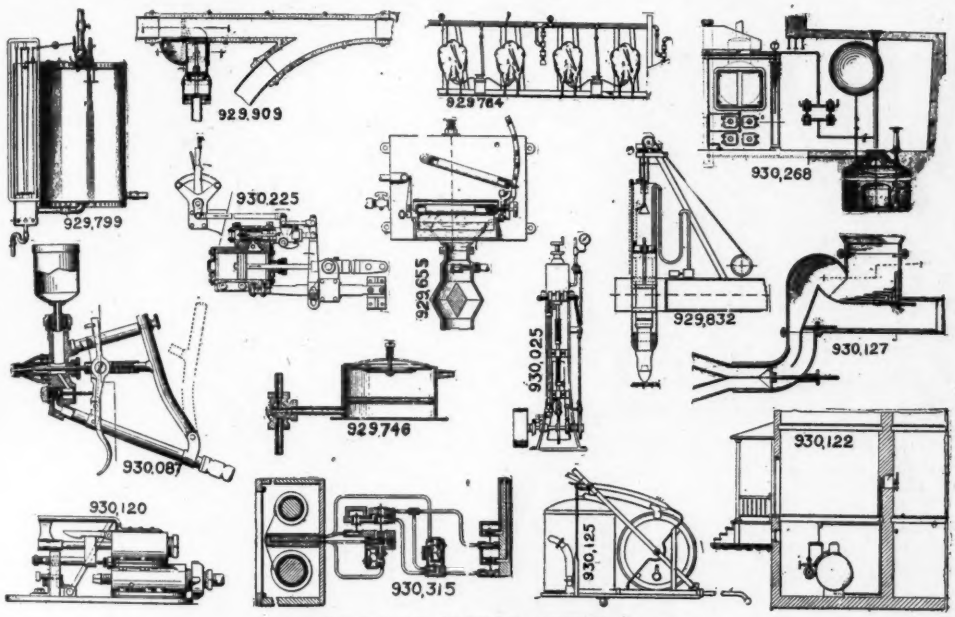
930,656. AIR AND GAS MIXER. CHARLES A. FORSBERG, Rockford, Ill.

930,781. AIR-PUMP. EDWARD J. MCCUTCHEN, Mexico, Mexico.

930,786. COOLER AND AERATOR. FRANK R. NOONAN. Alexandria, Minn.

930,794. WINDMILL AND CLUTCH THEREFOR. FRITZ W. PIERSON, Missoula, Mont.

930,833. PULSATOR FOR MILKING-MACHINES. DAVID BROWN. Spokane, Wash.



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2. In a milking machine, the combination with suction mechanism, an oscillating pulsator for intermittently interrupting the suction and having a spiral groove formed therein, a motor, and means carried by the motor and extended within the groove of the pulsator for actuating the latter.

930,841. INHALER. HUBERT P. COLLINS, East Orange, N. J.

930,843. APPARATUS FOR CONTROLLING THE FLOW OF FLUIDS. SAMUEL COOK, Wilmerding, Pa.

1. In combination with a compressor, a receiver receiving fluid therefrom, a blow-off valve for said receiver, a fluid-actuated supply valve controlling the delivery of fluid to said compressor, a normally balanced controlled valve controlling the delivery of actuating fluid to said supply valve and provided with means whereby it is unbalanced and caused to deliver actuating fluid to the supply when said blow-off valve is opened.

930,851. AIR-BEARING FOR HIGH SPEEDS. SEBASTIAN ZIANI DE FERRANTI. Hampstead, London, England.

1. An air bearing having in combination a bearing member; a high speed rotable member; one or more running members disposed between said bearing and said high speed rotatable members together with air lubricated surfaces on coacting bearing portions of said members.

930,893. VACUUM-VALVE FOR HEATING SYSTEMS. FRANK SHURTLEFF, Moline, Ill.

930,950. METHOD OF SEALING VACUUM-JACKETS. JOHN L. FATE, Chicago, Ill.

930,989. CONVERTIBLE SYSTEM OF PRESSURE OR VACUUM CONTROL. WALTER J. RICHARDS, Milwaukee. Wis.

931,009. PNEUMATIC LIFE-JACKET. PETER B. GAUDET, Chelsea. Mass.

931.014. AIR-FILTER. MINDELIN MCGERRY, Grand Rapids, Mich.

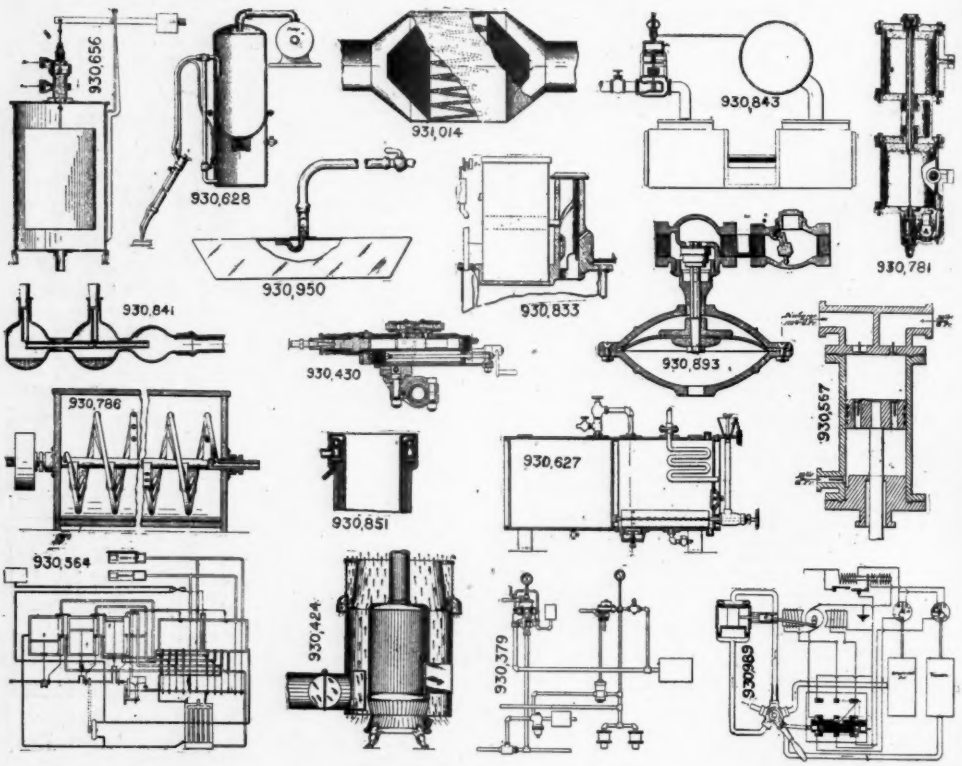
931,215. AIR-CHAMBER FOR LIQUID-SPRAYING DEVICES. ADELBERT M. PHILLIPS, La Roy, N. Y.

931,222. PNEUMATIC ELEVATOR. AUGUST ROSENTHAL, West Allis, Wis.

931.225. AIR-SHIP. REINHOLD SCHMIECHEN, Newell, Iowa.

931,229. APPARATUS FOR PURIFYING GASES. FRANCOIS SEPULCHRE, Liege, Belgium.

1. An apparatus for purifying blast-furnace and other gases, with a view to the recovery of their by-products, comprising a straight, vertical column, said column receiving the gases at its upper end and being open at its lower end, said lower end being restricted by a central cone to form an annular opening, said opening being immediately over a bath of liquid, an atomizer placed at the top of said column, said atomizer being operated by compressed gas, a spray of liquid from said atomizer descending down said column, a compressor, said compressor taking a portion of the purified gases and delivering them to operate said atomizer, said spray of liquid absorbing the impurities from said gases and being projected therewith into said bath of liquid and a pipe for the escape of the purified gases.



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AUGUST 17.

931,026. AERODART. CAESAR R. BANNIHR, New York, N. Y.

931,030. SPRAYER. D. O. BOWMAN. Rockford, Mich.

931,039. ROTARY VALVE FOR WIND MUSICAL INSTRUMENTS. CHARLES G. CONN, Elkhart, Ind.

931.057. MINING APPARATUS. MANNING GOLDSMITH, Atlanta, Ga.

1. In mechanism of the character described, the combination with means for closing the mouth of a mine or similar cavity, of means for introducing a liquid under pressure into said mine or cavity, means for again withdrawing the introduced liquid and dislodged material from said mine or cavity, and means for supplying air under pressure to said mine or cavity.

931,135. PROCESS OF PRODUCING MOTIVE FLUID. HUDSON MAXIM, New York, N. Y.

931,234. AIR-BRAKE SYSTEM. EDWIN M. SWIFT, Ballard, Wash.

931.240. ATOMIZER. ROBERT F. VENNER and ARTHUR W. BROWN, London, England.

931,255. FIRE-EXTINGUISHER AND OTHER AIR-PRESSURE LIQUID-EJECTING VESSEL. HENRY T. BLAKE, Ross, England.

931.297. APPARATUS FOR DRAWING BEER. LUCIEN H. HANDY and WALTER L. PHILLIPS, San Francisco, Cal.

931,341. BLASTING DEVICE. JACOB PHILLIPS, Bellaire, Ohio.
931,348. BLAST AND PRESSURE METER. EDWARD H. SCHULZ, Fort Wadsworth, N. Y.
931,449. PERCUSSION-ENGINE. WILHELM MAUSS, Brakpan, Transvaal.
931,479. ROCK-DRILL. WILLIAM E. PORTER, Bisbee, Ariz.
931.579. SAND-BLAST BLOWER. DIEDERICH A. M. DOUBLET, Eimsbuttel, near Hamburg, Germany.
931,609. FLUID-PRESSURE HAMMER. LESLIE E. HOWARD, La Grange, Ill.
931,611. ROCK-DRILL OR BORING-TOOL. JOHN HUTCHINGS, London, England.
931,643. AIR MOTOR OR LOCOMOTIVE. JAMES I. PITTMAN and ELIZABETH HARRISON, Valdosta, Ga.
931.648. INNER TUBE OF PNEUMATIC TIRES. HARRY K. RAYMOND, Akron, Ohio.
931,650. AIR-VALVE GEAR. EDWARD A. RIX, San Francisco, Cal.
13,012. JARRING-MACHINE. WILFRED LEWIS, Philadelphia, Pa. (Reissue).
931,845. HUMIDIFIER. FRANK B. COMINS. Sharon, Mass.
931.942. TRIPLE VALVE FOR AIR-BRAKES. WILLIAM B. MANN, Baltimore, Md.
931,964. INTERNAL-COMBUSTION ROCK-DRILL. LEWIS L. SCOTT, Joplin, Mo.
932,068. SUCTION-HEAD FOR VACUUM COTTON-PICKERS. JOHN S. THURMAN. St. Louis, Mo.
932.124. MINING-MACHINE. JOHN HERZLER, HENRY HENNINGER. and WILLIAM FENNER, Belleville, Ill.
932,143. AIR-PUMP. AUGUST M. KJAERSGAARD, Copenhagen, and CARL S. J. WIESE, Odense, Denmark.
932,221. AERATING AGITATOR FOR LIQUIDS. RICHARD D. WINSHIP, Chicago, Ill.
932.421. VALVE SYSTEM FOR HAMMERS. CHESTER B. ALBREE, Pittsburg, Pa.

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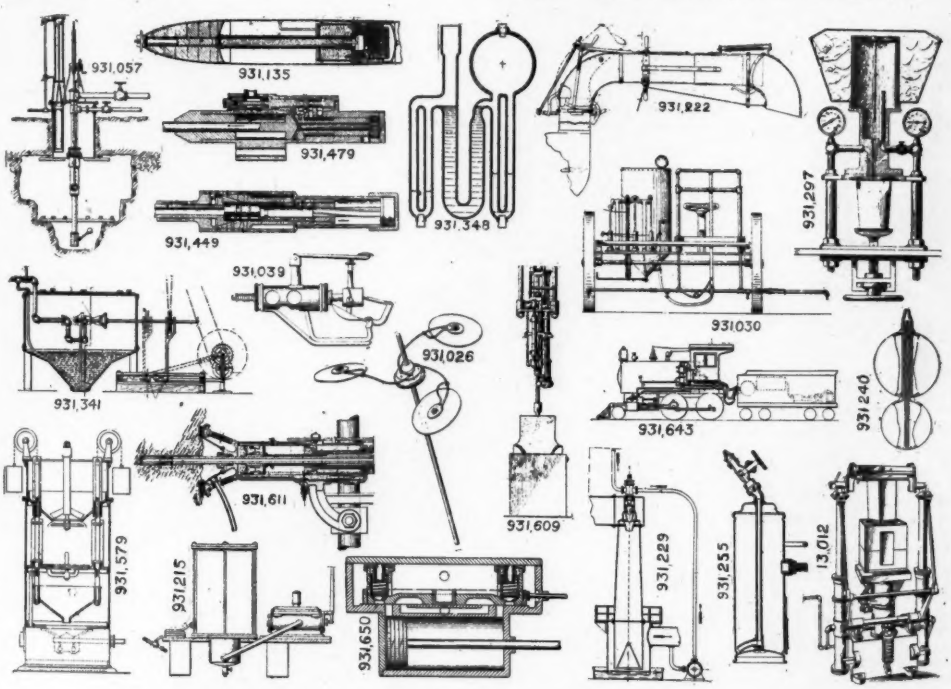
932.504. FLUID-PRESSURE-INDICATING DEVICE. THOMAS SLOPER, Devizes, England.



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AUGUST 24.

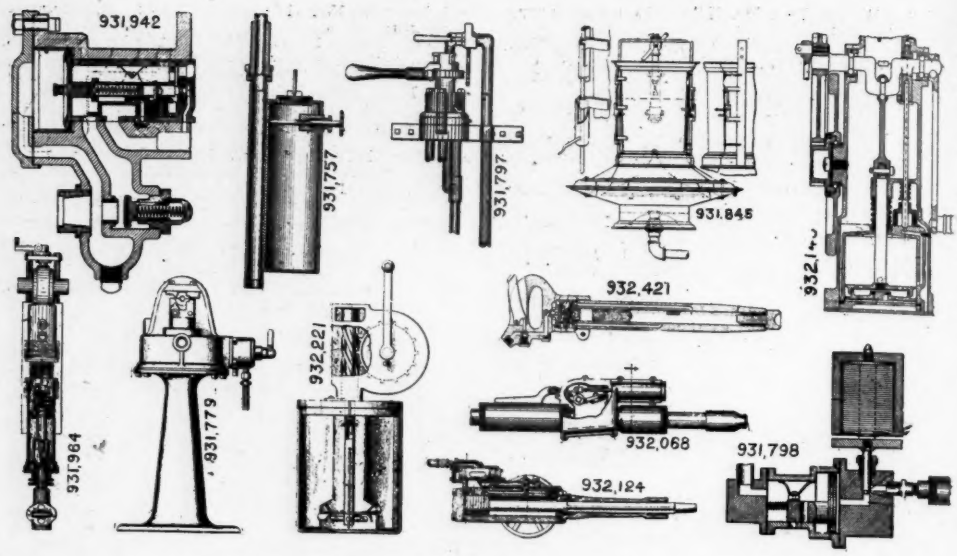
931,757. PNEUMATIC MACHINERY-CLEANER. EDWARD HARMER, Ottawa, Ontario.
931,779. FLUID-CONTROLLED DRILL-BIT SWAGING AND SHARPENING MACHINE. JOHN G. LEYNER, Denver, Colo.
931,797. VALVE. FRANK R. PHILLIPS and REX G. AVERILL, Mansfield. Ohio.

1. In a sander valve, a body provided with a casing, means to open and close the valve, an oscillating lever secured to the valve, a removable operating lever interposed between the oscillating lever and valve stem, both of said levers being adapted to be moved through the medium of the operating handle of the engineer's air brake valve.

931,798. AUTOMATIC BRAKE-APPLYING MECHANISM. FRANKLIN A. PIERCE. Wheeling, W. Va.
932,520. PORTABLE SPRAYING APPARATUS. DWIGHT W. WADSWORTH, Bangor. Mich.
932,521. WIND-WHEEL FOR WINDMILLS. HUGH M. WALLACE, Clovis, N. Mex.
932,686. DRY SEPARATOR FOR DUST-REMOVING APPARATUS. RALPH F. DISERENS. Bradford, Pa.
932,689. PROCESS OF OXIDIZING ORES. BYRON E. ELDRED, Bronxville, N. Y.

1. The process of treating sulfied ores which consists in oxidizing such ores with draft currents of air diluted with controlled proportions of non-oxidizing gases.

932,711. TEMPERATURE-REGULATING SYSTEM. CHARLES D. KNIGHT, Schenectady, and WALTER O. LUM. Amsterdam, N. Y.
932,712. AIR-SHIP. ENOCH S. LE FEVRE. Littlestown, Pa.. and WILLIAM D. LE FEVRE, Smyrna. Del.



PNEUMATIC PATENTS AUGUST 24.

932,761. CAR-VENTILATING SYSTEM. DWIGHT I. COOKE, Chicago, Ill.

932,885. SPEED-GAGE. ORSON D. MUNN and JOHN K. BRACHVOGEL. New York, N. Y.

1. A speed gage, comprising a cylinder having communicating openings, a piston mounted within said cylinder between said openings, indicating means controlled by said piston, and a blower in said cylinder adapted to force air against said piston.

932,916. APPARATUS FOR REMOVING GASES AND FOUL AIR FROM MINES. JOSEPH C. STIRLING, Bakerstown, Pa.

932,934. AIR-LIFT. ROBERT N. WOOD, Point Richmond, Cal.

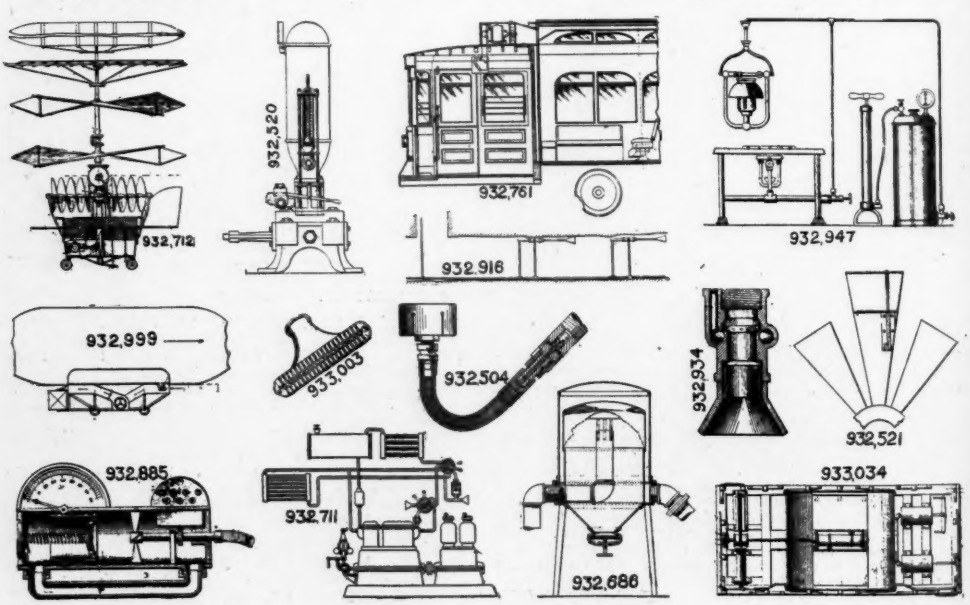
932,947. COMBINED LIGHTING AND HEATING SYSTEM. HOMER A. BARR, Ashland, Pa.

932,997. ACETYLENE-GAS APPARATUS. LARS J. OLSON, Alexandria, Minn.

932,999. AIR-SHIP. JOSEPH A. RIGNON, Berlin, Germany.

933,003. NOZZLE FOR VACUUM-CLEANERS. JOHN W. SMITH, Philadelphia, Pa.

933,034. COMPRESSED-AIR DOOR-CLOSER. ALBERT E. HANSON, Wakefield, Mich.



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